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D i p l o m a r b e i t

Operation and Maintenance of Resource-Oriented Sanitation Systems in Peri-Urban Areas

Betrieb und Instandhaltung kreislauforientierter Sanitärsysteme in peri-urbanen Gebieten

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Usipoziba ufa, utajenga ukuta.[1]

1 Swahili saying; literally it means: “If you do not fill up a crack, you will have to build a wall.” - as to say: “A stitch in time saves nine.”

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Acronyms and Abbreviations

BOD	Biochemical oxygen demand
BOO	Build-own-operate (contractual agreement)
BOOT	Build-own-operate-transfer (contractual agreement)
BOT	Build-operate-transfer (contractual agreement)
C:N ratio	Ratio of carbon to nitrogen
CBO	Community based organisation
COD	Chemical oxygen demand
Ecosan	Ecological Sanitation
FS	Faecal sludge
FSM	Faecal sludge management
HRT	Hydraulic retention time
IEC	Information, education and communication
K	Potassium
Ksh	Kenya Shillings
N	Nitrogen
NAHECO	Nakuru Affordable Housing and Environmental Committee
NAWACOM	Nakuru Waste Collectors and Recyclers Management
NGO	Non-governmental organisation
NH_4-N	Ammonium nitrogen
MCN	Municipality of Nakuru
MDG	Millennium Development Goal
MEWAREMA	Menengai Waste Recyclers Management
MFI	Microfinance institution
O&M	Operation and maintenance
P	Phosphorus
PPP	Public-private partnership
PSSP	Private small scale service provider
ROSA	Resource-oriented sanitation concepts for peri-urban areas in Africa

ROT	Rehabilitate-Operate-Transfer (contractual agreement)
SACCO	Savings and Credit Cooperative Society
SSWP	Strategic sanitation and waste plan
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TP	Total phosphorus
TS	Total solids
TSS	Total suspended solids
VIP	Ventilated improved pit latrine
WSS	Water supply and sanitation

Deutsche Zusammenfassung

Einleitung

Diese Diplomarbeit wurde im Rahmen des EU-Projects 'Resource-oriented sanitation concepts for peri-urban areas in Africa' (ROSA)[2] erstellt. ROSA wird in vier Städten Ost-Afrikas in Zusammenarbeit mit europäischen Partnern kreislauforientierte Sanitärkonzepte umsetzen. Bei dieser Arbeit handelt es sich um eine Literaturstudie, welche durch eine Feldstudie um praktische Inhalte ergänzt werden konnte.

Hintergrund

Die Bevölkerungszahl der meisten Entwicklungsländer nimmt exponential zu. Brennpunkte dieses Wachstums sind die Städte, die zusätzlich noch unter dem Druck der Zuwanderung aus ländlichen Gebieten leiden. Die Folgen dieser rapiden Urbanisierung sind wuchernde Siedlungen an den Stadträndern, welche meist von ungeplanter Bebauung, Armut, mangelhafter Infrastruktur und schlechter Trinkwasserversorgung gekennzeichnet sind. Diese Gebiete nennt man ‚peri-urbane' Gebiete. Zusätzlich verschlimmert die unzulängliche Entsorgung von Abfällen und Abwässern die Situation und unhygienische Umweltbedingungen führen oft zu Krankheit und Tod. Weltweit sterben täglich 4900 Kinder an Durchfallerkrankungen und fast die Hälfte der Bevölkerung in Entwicklungsländern leidet unter Gesundheitsproblemen im Zusammenhang mit Trinkwasser und mangelhafter Hygiene.

Im September 2000 wurden durch die Regierungsvertreter der Staatengemeinschaft die Millennium Entwicklungsziele festgelegt, deren Ziel es ist, die Armut zu bekämpfen und die Lebensbedingungen der Menschen zu verbessern. Ein angestrebtes Ziel ist es, die Anzahl der Menschen, die keinen nachhaltigen Zugang zu sauberem Trinkwasser und grundlegender Sanitärversorgung haben, bis 2015 zu halbieren. Dies bedeutet, dass bis dahin mehr als 1,2 Milliarden Menschen mit sanitären Systemen[3] und mehr als 600 Millionen Menschen mit sauberem Trinkwasser versorgt werden müssen. Vor allem in Afrika, südlich der Sahara, wo 72 % der Stadtbewohner in Slums leben und 60 % keine ausreichende sanitäre Versorgung haben, besteht großer Handlungsbedarf.

Problemstellung

Eine paradoxe Situation hat sich hinsichtlich der städtischen Versorgung in Entwicklungsländern entwickelt. Auf der einen Seite führt die rasche Verstädterung zu einem enormen Bedarf an Infrastruktur; auf der anderen Seite jedoch verfallen die bestehenden Einrichtungen lange bevor sie ihr Nutzungshöchstalter erreicht haben. Nachhalti-

[2] Zu Deutsch: „Kreislauforientierte Sanitärkonzepte für urbane Randgebiete Ostafrikas."

[3] ‚Sanitäre Systeme' oder ‚Sanitärsysteme' umfassen alle Anlagen und Systeme, die an Sammlung, Transport, Behandlung, Wiederverwertung oder Entsorgung der entsprechenden Stoffströme beteiligt sind.

ger Betrieb und Instandhaltung, auf Englisch ‚Operation and Maintenance (O&M)` genannt, sind der Schlüssel zu einer Verbesserung der Situation.

Im Zusammenhang mit dezentralen kreislauforientierten Systemen für Entwicklungsländer besteht oft ein erhöhter Aufwand für den Betrieb der Anlagen. Abfälle, Abwässer und Exkremente müssen gesammelt, hygienisiert und recycelt werden. Um die Nachhaltigkeit eines solchen Projektes zu gewährleisten, muss man sich bereits vor der eigentlichen Investition über O&M und somit auch über das Management der bereitgestellten Systeme Gedanken machen.

Zielsetzung und Fragestellung

Mittels einer Literaturstudie sollten die Rahmenbedingungen, die für die Nachhaltigkeit des Betriebes kreislauforientierter Sanitärsysteme in peri-urbanen Gebieten in Entwicklungsländen notwendig sind, ermittelt und dargestellt werden. Insbesondere sollte hierbei auf folgende Fragestellungen eingegangen werden:

- Welche Betreibermodelle und Arten der Zusammenarbeit sind möglich, bzw. funktionieren?
- Welche Finanzierungsmöglichkeiten für O&M der Systeme gibt es?

Die angesprochenen Sanitärkonzepte beinhalten die Entsorgung und Verwertung von Abfall, Abwässern und Exkremente. Der Schwerpunkt der Arbeit liegt hierbei auf der Entsorgung und Wiederverwertung von menschlichen Ausscheidungen und häuslichem Abwasser, was auch den Schwerpunkt des ROSA Projektes widerspiegelt.

Im Anschluss an die Literaturarbeit folgt noch eine kurze Fallstudie. Während eines zweiwöchigen Aufenthaltes in Nakuru, Kenia sollten folgende Fragen beantwortet werden:

- Was sind die Hauptprobleme des Betriebs bestehender Anlagen in Nakuru?
- Welche Behörden, Organisationen und Gruppen sind beteiligt und welche Rollen spielen sie?
- Wie gut eignet sich die vorhandene Kompostierungsanlage für eine Co-Kompostierung von Bioabfall mit Exkrementen?

Kreislauforientierte Sanitärkonzepte

Bevor kreislauforientierte Konzepte näher beschrieben werden, sollte noch einmal kurz auf die Nachteile der bestehenden Abwasserkonzepte eingegangen werden.

Hintergrund

Das ‚drop-and-store' Konzept

Als ‚drop-and-store' werden sanitäre Systeme verstanden die darauf basieren menschliche Ausscheidungen vor Ort zu lagern. Dies geschieht in Gruben oder Kammern die unter den Toiletten angebracht sind und Fäkalien und Urin aufnehmen und speichern. Flüssigkeiten versickern durch die porösen Außenwände oder werden bewusst als

Ablauf Sickergruben zugeführt und verfrachten somit Krankheitserreger und Nährstoffe in Grund- und Oberflächengewässer. Zurückbleibender Fäkalschlamm muss entweder regelmäßig entfernt werden oder es müssen neue Latrinen angelegt werden. Die Entleerung der Gruben geschieht oft manuell und auf unhygienische Weise. Anfallende Schlämme werden meist unkontrolliert ins Umland oder in Gewässer eingebracht und tragen somit zur weiteren Umweltbelastung und Krankheitsgefahr bei. Mehr als 90 % der Bevölkerung in afrikanischen Städten südlich der Sahara ist auf solche Systeme angewiesen.

Konventionelle Abwasserwirtschaft

Das Konzept der Schwemm-Kanalisation und der zentralen Abwasserreinigungsanlage wurde in Industrieländern über viele Jahrzehnte hinweg entwickelt und perfektioniert. In Entwicklungsländern wird es von vielen als Symbol für einen hohen Lebensstandard betrachtet. Die Einführung dieses Systems in diesen Ländern bringt allerdings viele Probleme mit sich. Das herkömmliche Abwasserentsorgungssystem widerspricht in vielerlei Hinsicht dem Prinzip der Nachhaltigkeit und weist Nachteile ökologischer und ökonomischer Natur auf. So ist die Verwendung von Trinkwasser als Transportmedium menschlicher Ausscheidungen als Verschwendung von natürlichen Wasserressourcen zu bewerten. Enthaltene Stoffe können nach Verdünnung mit Wasser und Vermischung mit unzähligen anderen Stoffen nur mit großem technischem Aufwand abgetrennt oder zu harmlosen Produkten umgewandelt werden. Die im Abwasser enthaltenen Nährstoffe wie Phosphor (P) und Stickstoff (N) werden oft mit hohem Energieaufwand und unter Einsatz von Chemikalien aus dem Abwasser entfernt. Global gesehen gelangt ein Großteil dieser Stoffe jedoch immer noch über den Kläranlagenablauf in die Gewässer und geht als Düngemittel der Landwirtschaft verloren. Zur Kunstdüngerherstellung müssen nicht erneuerbare Vorräte an Phosphor abgebaut werden. Der Bau und O&M von Kanälen und Kläranlagen werden in Industrieländern meist stark subventioniert und stellen für die meisten Länder Afrikas aufgrund der hohen Kosten unüberwindbare finanzielle Schwierigkeiten dar. Lediglich in den relativ wohlhabenden und dicht besiedelten Stadtzentren konnte dieses Konzept mancherorts umgesetzt werden.

Das Ecosan Konzept

Ecosan ist ein ganzheitliches Sanitärkonzept, das auf der systematischen Schließung lokaler Stoffkreisläufe basiert. Der Grundgedanke lautet etwa: „Wiederverwertung von Abwasser und Fäkalien ist nachhaltiger und wirtschaftlicher als deren Einleitung in die Oberflächengewässer."[4]

Trennung der Stoffströme aus dem Haus, Wertstoff- und Energiegewinnung sowie Reduzierung des Wasserverbrauchs auf ein ökologisch verträgliches Maß sind die wesentlichen Merkmale dieses Konzeptes. Die Einhaltung hygienischer Grundanforderungen, Vermeidung jeglicher Umweltverunreinigung, Rückführung wertvoller Nährstof-

[4] Quelle: http://www.gtz.de/ecosan

fe in den Boden, Wirtschaftlichkeit und Erschwinglichkeit auch für Personen mit niedrigem Einkommen sind die wichtigsten Randbedingungen.

Im Gegensatz zu herkömmlichen Konzepten betrachtet man bei Ecosan die anfallenden Stoffströme nicht als Abfälle die es zu entsorgen gilt, sondern als Ressourcen, welche wiederverwertet werden können. Es findet hierbei eine Einteilung in Teilströme statt. Urin, Fäkalien und Grauwasser[5] werden möglichst getrennt gesammelt, behandelt und der Wiederverwertung zugeführt. Angewendete Systeme sind meist dezentral. Es gibt verschiedene technische Lösungen, von hochtechnischen Vakuumtoilettensystemen bis zu billigen Trockentoiletten, jedoch zielen alle darauf ab, die Keime abzutöten (aerob durch Dekomposition, Hitze, Trockenheit und/oder Zugabe basischer Zusatzstoffe; anaerob durch Faulung und Biogasproduktion) und als Endprodukt hygienische Rohstoffe zur Wiederverwertung, vor allem in der Landwirtschaft, zu produzieren. Aber auch das nachhaltige Management von Fäkalschlämmen aus den bestehenden ‚drop-and-store' Einrichtungen kann den Ansprüchen kreislauforientierter Konzepte entsprechen und sollte bei Projekten in Entwicklungsländern als integrierter Bestandteil des Ecosan Konzeptes verstanden werden.

Charakterisierung der Teilströme

Ein Mensch scheidet etwa 550 Liter Urin und 50 – 200 kg Fäkalien pro Jahr aus. Je nach den lokalen Gegebenheiten produziert ein Mensch jährlich von 8.000 bis zu über 100.000 Liter Grauwasser. Beim Vergleich der Stoffinhalte der verschiedenen Teilströme ergibt sich, dass die landwirtschaftlich verwertbaren Pflanzennährstoffe fast vollständig in den Fäkalien und im Urin zu finden sind. Während die partikulär gebundenen Stoffe hauptsächlich im festen Anteil der Fäkalien enthalten sind, kommen gelöste Nährstoffe beinahe ausschließlich im Urin vor. Obwohl Urin nur einen geringen Anteil der gesamten Abwassermenge ausmacht, enthält er den weitaus größten Teil an Nährstoffen. Er enthält circa 87 % an Gesamtstickstoff, 50 % des Phosphors und 54 % des Kaliums. Grauwasser enthält weniger als 50 % der Frachten an Kohlenstoff (C) des häuslichen Abwassers und nur noch einen geringen Anteil an Pflanzennährstoffen.

Pathogene Keime sind hauptsächlich in den Fäkalien zu finden während Urin und Grauwasser als eher unbedenklich gelten. Vor allem Urin weist nur geringe Keimzahlen auf und kann nach einigen Wochen bis Monaten Lagerung (je nach Lagerungstemperatur) bedenkenlos als hochwertiger Dünger ausgebracht werden. Fäkalien und Fäkalschlämme können einen hohen Anteil an potentiell gefährlichen Krankheitserregern enthalten. Oral übertragbare Durchfallerkrankungen und parasitäre Erreger zählen zu den größten Bedrohungen die hiervon ausgehen.

Kreislauforientierte Sanitärsysteme

Ein kreislauforientiertes Sanitärsystem besteht in der Regel aus (A) einer Anlage auf dem Haushaltslevel, (B) einem System/ einer Technologie zum sammeln und transpor-

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[5] Als Grauwasser bezeichnet man Haushaltsabwässer die nicht aus der Toilette stammen.

tieren der Teilströme, (C) einer Behandlung der Teilströme, (D) einem Transportsystem zum Ort der Wiederverwertung und (E) der Wiederverwertung der behandelten Teilströme. In ländlichen Gebieten ist es möglich diesen Gesamt-Prozess auf dem Grundstück der Bewohner ablaufen zu lassen – es gibt zum Beispiel Trockentoiletten die es ermöglichen die Teilströme zu hygienisieren und im eigenen Garten wieder zu verwenden. In peri-urbanen Gebieten ist dies meist nicht möglich da die Besiedelungsdichte zu hoch ist. Dies macht eine kommunale/ städtische Aufsammlung und Behandlung der Ströme notwendig.

(A) Toilettensystem

Vorherrschende Toilettensysteme in Afrika sind Latrinen und ‚Septic-tanks'. Bei der Latrine fallen die Ausscheidungen in eine Grube die sich unter der Toilette befindet und werden dort gelagert. Flüssigkeiten können durch die porösen Wände versickern (und anstehendes Grundwasser eindringen). Septic-tanks sind dichte Betonkammern die das Abwasser aus einer Spültoilette und oft auch Grauwasser aufnehmen. Die Kammer ist meist zweigeteilt und eine Abtrennung von Feststoffen findet durch Sedimentation und Flotation statt. Flüssigbestandteile werden über einen Ablauf in Sickergruben eingeleitet.

Im Ecosan Konzept häufig angewendete Anlagen sind Dehydrierungs- und Komposttoilettensysteme. Vor dem Hintergrund der weit verbreiteten Armut in Afrika sind es vor allem einfache ‚lowtech' Lösungen die hierbei bedeutend sind. Ecosan Technologien stellen relativ hohe Betriebsansprüche an die Benutzer und es bedarf daher einer grundsätzlichen Aufklärung und Unterstützung von Haushalten die sich ein solches System anschaffen. Kulturelle Hindernisse erschweren die Verbreitung des Ecosan Konzepts. In vielen Kulturkreisen ist die Verwendung der eigenen, wenn auch behandelten, Exkremente als Dünger für Nahrungsmittel nicht akzeptiert. Bei Abfallstoffen ist auch oft ein ‚Aus den Augen, aus dem Sinn' - Prinzip zu beobachten.

Komposttoiletten können komplett oberirdisch oder mit der Kammer unterirdisch angelegt werden. In der Kompostierungskammer unter der eigentlichen Toilette werden der Urin und die Fäkalien gesammelt. Durch die Zugabe organischen Materials (Stroh, Blätter, Bioabfall etc.) und den Verzicht auf Spülwasser kann bei richtigem Betrieb Kompostierung stattfinden. Hierbei werden zwar selten thermophile Temperaturen von 45–70 °C erreicht (welche Keime schnell töten und die Mineralisierung der organischen Substanz beschleunigen), jedoch wird durch ausreichende Verweilzeit eine Hygienisierung der Fäkalien erreicht. Am häufigsten werden Toiletten mit zwei Kammern angewendet, wobei nur immer eine Kammer betrieben wird, während der Inhalt der zweiten Kammer lagert. Durch entsprechende Dimensionierung der Kammern, können diese jeweils für ein Jahr betrieben werden, während in der anderen Kammer der Inhalt des Vorjahres kompostiert. Ist die benutzte Kammer beinahe voll kann der Kompost aus der anderen Kammer bedenkenlos herausgeholt werden, da er nun zu humosem Material abgebaut wurde.

Dehydrierungstoiletten basieren auf einem ähnlichen Prinzip. Auch hier befinden sich unter der eigentlichen Toilette eine oder zwei Kammern. In diese Kammern gelangen jedoch nur die Fäkalien, während der Urin durch das spezielle Design abgetrennt gesammelt werden kann (= Separationstoilette). Nach jedem Stuhlgang wird trockenes Feinmaterial (Asche, Kalk, Erde, Sägemehl etc.) beigegeben und trägt somit zur Austrocknung bei. Der Hygienisierungseffekt in der Dehydrierungstoilette basiert, wie es schon der Name sagt, auf dem Entzug von Wasser aus den Fäkalien. Die Zugabe von Kalk oder Asche wirkt durch einen Anstieg des pH-Wertes zusätzlich keimtötend. Nach circa einem Jahr sind die Fäkalien vollständig hygienisiert und können entnommen werden. Im Gegensatz zur Komposttoilette ist das hierbei anfallende Material kaum mineralisiert und Klopapierrückstände sind nicht abgebaut worden. Der getrennt gesammelte Urin kann in Kanistern oder größeren Tanks bis zur Abholung bzw. Ausbringung gelagert werden.

Ein anderes System das vor allem in größeren Einrichtungen oder in öffentlichen Toiletten dicht besiedelter Gebiete eingesetzt wird ist die Biogas-Toilette. Hierbei gelangen Fäkalien und Urin gemeinsam in einen unterirdischen Biogasreaktor in dem das Material vergärt wird. Das entstehende Gas kann zur energetischen Nutzung verwendet werden. Meist werden diese Biogasanlagen kontinuierlich betrieben und der vergärte Schlamm wird durch den Gasdruck in eine zweite Kammer befördert, von wo aus er dann abgepumpt werden kann. Die Betriebsbedingungen der Anlage können stark schwanken – es gibt keine künstliche Wärmezufuhr und der Reaktor unterliegt den tages- und jahreszeitlichen Temperaturschwankungen. In tropischen Gebieten können wegen der hohen Temperaturen trotzdem relativ gute Abbauwerte erreicht werden und der anfallende Schlamm ist zumindest teilweise hygienisiert. Biogastoiletten sind relativ aufwändig im Betrieb und teuer in der Anschaffung, haben dafür aber den Vorteil der Gas- und Energieproduktion und sind relativ wartungsarm.

(B) Sammlung und Transport

Wie bereits erwähnt, können oder wollen die Besitzer von Kompost- und Dehydrierungstoiletten die anfallenden Produkte oft nicht selbst wiederverwerten. Auch das Grauwasser der Haushalte, Fäkalschlämme aus Latrinen, Septic-tanks und Biogasanlagen müssen gesammelt werden. Deshalb muss ein System zur Aufsammlung und zum Transport bereitgestellt werden. Eine gute Organisation und durchdachtes Management von Transportsystemen wirkt sich entscheidend auf die Nachhaltigkeit des Gesamtsystems aus. Man unterscheidet zwischen Infrastruktur basierten Transportsystemen, wie zum Beispiel Kanalnetzen, und logistischem Management. Hierzu zählen LKWs, Pumpfahrzeuge, Dreiräder, Fahrräder und vieles mehr.

Grauwasser wird für gewöhnlich in Kanälen oder Rohren transportiert. Fäkalschlämme können von verschiedenen Saugfahrzeugtypen gesammelt und transportiert werden. Für getrocknete Fäkalien und Kompost kommen verschiedenste Transportmittel wie LKWs, motorisierte Dreiräder oder Ähnliches in Frage. Urin kann entweder von Saugfahrzeugen gesammelt und transportiert werden oder in Kanistern oder Fässer gefüllt auf Fahrzeuge verladen werden.

(C) Behandlung

Für die gesammelten Fraktionen ist eine (sekundäre) Behandlung notwendig. Auch bereits behandelte Teilströme aus Kompost/ Trockentoiletten sollten nachbehandelt werden, da mit den Teilströmen auch die Verantwortlichkeit für die hygienische Unbedenklichkeit von den Haushalten ‚exportiert' wurde.

Die höchsten Anforderungen an die Behandlung stellen Fäkalschlämme welche erst entwässert werden müssen bevor Flüssig- und Festbestandteile getrennt der Weiterbehandlung zugeführt werden können.

Es gibt für alle anfallenden Teilströme eine Auswahl an kostengünstigen Behandlungsmethoden die meist von den hohen tropischen Temperaturen profitieren. Es soll hierbei nicht näher auf die einzelnen Verfahren eingegangen werden – siehe hierfür die Diplomarbeit.

(D) Transport und (E) Wiederverwertung

Transport zum Ort der Wiederverwertung und die Wiederverwertung selbst ist entweder die Zuständigkeit des Käufers oder die der Betreiberorganisation. Das Endprodukt der meisten Behandlungsverfahren ist ein humusartiges nährstoffreiches Material das bodenverbessernde und düngende Eigenschaften hat. Karge Böden können wieder fruchtbar gemacht und Äcker aufgewertet werden. Urin kann direkt als Dünger verwendet werden und behandeltes Grauwasser der Bewässerung dienen. Es wird davon ausgegangen dass sich Käufer für die Produkte finden und daher die Schritte (D) und (E) nicht mehr die Zuständigkeit der Betreiber sind.

Betrieb und Instandhaltung

O&M sanitärer Systeme wird in der Konzeption von Entwicklungshilfeprojekten oftmals vernachlässigt. Bereitgestellte Infrastruktur und Systeme sind dem Verfall preisgegeben, wenn nicht von vorneherein für nachhaltiges betriebliches Management, inklusive Wartung, und entsprechende Finanzierungsmethoden gesorgt wurde.

Forschungsdefizite

Forschungsdefizite bestehen vor allem im Ecosan Bereich. Da Ecosan ein noch relativ junges Konzept ist und bisherige Erfahrungen vor allem aus ländlichen Gebieten stammen existiert wenig Erfahrung über den Betrieb kreislauforientierter Systeme in urbanen und peri-urbanen Gebieten. Hierbei sind vor allem logistische Aspekte und dezentrale Betreibermodelle wenig erforscht. In den wenigen bestehenden Pilotprojekten in Städten von Entwicklungsländern hat man festgestellt, dass die großflächige Aufsammlung und Speicherung von Urin mit erheblichen finanziellen Aufwendungen verbunden ist. Hier müssen noch billigere Methoden zur Sammlung und Speicherung großer Mengen Urin entwickelt werden.

O&M und das Prinzip der Nachhaltigkeit

Die Probleme mit O&M in Entwicklungsländern basieren auf den erschwerten Bedingungen die ein finanziell und strukturell wenig gut ausgestattetes Umfeld mit sich bringt. Gründliche Planung und eine gute Kenntnis lokaler Gegebenheiten sind daher eine Vorbedingung für den bestehenden Erfolg eines Projektes. In diesem Zusammenhang ist es hilfreich den Begriff der Nachhaltigkeit genauer zu definieren.

Ein Service[6] ist nur dann nachhaltig wenn er folgende Bedingungen erfüllt:

- Er funktioniert richtig und wird verwendet
- Er stellt die Leistungen zur Verfügung für die er geplant und konzipiert wurde
- Er funktioniert über einen längeren Zeitraum, entsprechend der geplanten Lebensdauer der Anlagen
- Das Management bezieht die Verbraucher mit ein (oder die Verbraucher selbst managen das System), es achtet auf die Gleichberechtigung der Geschlechter, es arbeitet mit lokalen Behörden zusammen und es bezieht die Privatwirtschaft, wenn erforderlich, mit ein.
- Die Kosten für O&M, Wiederherstellung, Rehabilitation und Verwaltung werden auf lokaler Ebene durch Gebühren oder durch alternative, nachhaltige Finanzierungsmethoden gedeckt.
- Er kann auf lokaler Ebene gewartet und betrieben werden
- Er hat keine schädlichen Umweltauswirkungen

Nachhaltigkeit und effektives O&M basieren auf vier voneinander abhängigen Einflussfaktoren: (i) technische Faktoren, (ii) gesellschaftliche Faktoren, (iii) Umweltfaktoren und (iv) den rechtlichen und institutionellen Rahmenbedingungen.

Rechtliche und institutionelle Rahmenbedingungen

O&M sanitärer Systeme bedürfen einer guten Organisation und klarer Zuständigkeiten. Die rechtlichen- und institutionellen Rahmenbedingungen schaffen hierfür idealer Weise ein begünstigendes Umfeld.

Gesetzgebung

Im Zusammenhang mit kreislauforientierten Sanitärkonzepten kann die nationale Gesetzgebung eines Landes dazu beitragen technische Neuerungen voranzubringen und Finanzierungsmechanismen zu erleichtern. Zudem sollten die Gesetze die Zuständigkeiten und die Art der Zusammenarbeit relevanter Parteien, einschließlich der Privatwirtschaft, festlegen und in diesem Zusammenhang Mittel zur Kompetenzbildung, Aus- und Weiterbildung sowie zur Überwachung, Implementierung und Wartung zuweisen. Weiterhin sollte die Gesetzgebung eine Basis für die Durchsetzung von Richtwerten für die Sammlung, Behandlung und Wiederverwendung von Exkrementen und Grauwasser bilden. Effektive Gesetze, Verordnungen und Vorschriften setzen sowohl Anreize

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[6] Unter ‚Service' wird hier das Bereitstellen einer Ver- oder Entsorgungsleistung (Trinkwasser, Abfall und Abwasser, Elektrizität usw.) verstanden. Auch das Bereitstellen sanitärer Einrichtungen zählt dazu.

zum Einhalten der Vorgaben, als auch Auflagen für den gegenteiligen Fall fest. Dies alles kann meist durch die Anpassung bestehender Gesetze erreicht werden. Jedoch kann auch in seltenen Fällen der Erlass zusätzlicher Gesetze, Verordnungen und Vorschriften erforderlich sein. Die folgenden Bereiche bedürfen besonderer Aufmerksamkeit um die Durchführung eines kreislauforientierten Sanitärkonzeptes zu erleichtern:

- Festlegung institutioneller Zuständigkeiten oder Zuweisung neuer Befugnisse an bestehende Institutionen
- Etablierung von Zuständigkeiten der Zusammenarbeit zwischen nationalen und lokalen Behörden
- Festlegung von Eigentumsverhältnissen
- Entwicklung der Gesetzgebung auf den Gebieten der öffentlichen Gesundheitspflege und der Landwirtschaft im Zusammenhang mit Behandlungs- und Ausbringungsvorschriften für Exkremente und Grauwasser.

Institutionelle Rahmenbedingungen

In vielen Ländern findet derzeit ein Dezentralisierungsprozess statt, mit dem Ziel der Steigerung der Effektivität, Effizienz und Nachhaltigkeit öffentlicher Dienste. Dieser Prozess basiert auf der Annahme, dass lokale Einrichtungen besser auf die Bedürfnisse der ansässigen Bevölkerung eingehen können, indem sie ihre Politik und Entscheidungen den örtliche Gegebenheiten anpassen. Die nationalen Behörden müssen hierbei ihre Rolle vom Dienstleister zu der eines Vermittlers und Koordinators ändern. Dies kann durch den Transfer von Zuständigkeiten auf die lokalen Ebenen und die Auslagerung verschiedener Tätigkeiten an externe Parteien - zum Beispiel an regierungsunabhängige Organisationen (Non-governmental organisations - NGOs) oder an die Privatwirtschaft, geschehen. Als Folgen dieses Prozesses steigen die finanziellen, betrieblichen, technischen und verwaltungstechnischen Belastungen auf die Kommunen. Deshalb sollte gleichzeitig mit der Dezentralisierung auch eine Kompetenzbildung und Unterstützung der Kommunalverwaltungen und anderer Betroffener einhergehen. Leider findet dies oft nicht ausreichend statt und die kommunalen Behörden sind völlig überfordert mit den neuen Aufgaben. Viele Kommunen versuchen daher andere Institutionen und das Gemeinwesen an der Erbringung von Dienstleistungen zu beteiligen. Dies spiegelt sich auch in vielen Entwicklungsprojekten wieder. Es wird versucht, möglichst alle betroffenen oder interessierten Parteien in die Planung, Implementierung und den Betrieb mit einzubeziehen. Man spricht hier von der Involvierung der ‚Stakeholder', also der Miteinbeziehung einzelner Entscheidungsträger und möglicher Kooperationspartner.

Stakeholder im Sanitärbereich

Die relevanten Stakeholder sollten vor jeder sanitären Intervention in Entwicklungsländern ermittelt und analysiert werden. Die Aufteilung von Zuständigkeiten und Aufgaben kann bei guter Koordination die Nachhaltigkeit erheblich steigern.

Folgende Stakeholder könnten möglicherweise eine oder mehrere Rollen in O&M kreislauforientierter Sanitärsysteme spielen:

- Nutzer der sanitären Anlagen (O&M ihrer sanitären Anlagen)
- Nutzer der recycelten Stoffe (sind eventuell verantwortlich für Sammlung, Transport, Behandlung und Lagerung)
- Nachbarschaftsgruppen, Selbsthilfegruppen, Vereine (können Arbeitskräfte für O&M stellen und sich eventuell dann in private Dienstleister umwandeln; Training und Beratung von Verbrauchern und Dienstleistern)
- NGOs (Öffentlichkeitsarbeit; Werbung, Bewusstseinsbildung; Beraterfunktionen; Beschaffung von Geldmitteln; Training und Beratung von Verbrauchern und Dienstleistern)
- Lokale Behörden und Regierungseinrichtungen (Wartung und Rehabilitierung von Anlagen; direkte Dienstleistung auf kommerzieller Basis; Wiederverwertung recycelter Stoffe in Parks/ auf Grünflachen; Verantwortlichkeit, dass das System den gesetzlichen Normen entspricht bzw. Anpassung der Gesetzgebung durch entsprechende Verordnungen; Überwachung von Hygienevorschriften und Umweltstandards; Kompetenzbildung und klären der Verantwortlichkeiten; technische Unterstützung für Verbraucher und Dienstleister)
- Nationale Regierungseinrichtungen (Gesetzgebung; Finanzierung)
- Private Dienstleister (Wartung und Rehabilitation; Training und Beratung der Verbraucher; Sammlung Transport, Behandlung und Vermarktung der Stoffströme)
- Forschungseinrichtungen (Umweltüberwachung und Hygienische Untersuchungen; Fachberatung)

Die Aufteilung der Zuständigkeiten birgt die Gefahr von Kompetenzstreitigkeiten und Verwirrung. Deshalb ist eine effektive Koordinierung aller Aktivitäten und Zuständigkeitsbereiche essentiell.

Rollen und Zuständigkeiten in O&M

Es gibt die Ansicht, dass die Zuständigkeiten für O&M entsprechend eines mehr oder minder hierarchischen Systems – welches das hierarchische Prinzip des Sanitärsystems widerspiegelt – verteilt werden sollen. Man kann diese Hierarchie anhand des Beispieles der konventionellen Abwassernetze zeigen:

- Anlage im Haushalt (WC, Waschmöglichkeiten, etc.) ist angeschlossen an die
- Ortskanalisation, diese mündet in die
- Nebensammler der Kanalisation, diese sind wiederum angeschlossen an
- Hauptsammler welche letztlich in die Kläranlage führt.

Diese Hierarchie existiert auch bei dezentralen Konzepten, auch wenn sie hier nicht so leicht zu erkennen ist. Die Haushaltsanlagen müssen regelmäßig entleert und die Stoffe gesammelt und zu einer Behandlungsanlage transportiert werden, usw. Aus diesem Prinzip ergibt sich ungefähr die folgende Aufteilung von Zuständigkeiten in einer Stadt/ Kommune:

- Die Haushalte sind für gewöhnlich für O&M der Anlagen auf dem eigenen Grundstück zuständig
- Nachbarschaftsgruppen, ansässige NGOs, ansässige Unternehmer und lokale Zweige der Stadtverwaltung könnten eine Rolle im Management relativ einfacher lokaler Systeme spielen. Ihr direktes Interesse am Funktionieren der Anlagen führt für gewöhnlich zu einem besseren Management als dem einer weit entfernten Regierungsbehörde.
- Größere, formalere strukturierte Organisationen sind für das Management auf einem höheren Level zuständig. Dies werden oft Regierungsbehörden sein, obwohl in den letzten Jahren auch größere Privatunternehmer städtische Dienstleistungen übernommen haben.

Gesellschaftliche Rahmenbedingungen

O&M kann als ein Prozess angesehen werden der sowohl finanzieller als auch nicht-finanzieller Unterstützung bedarf. Die Beteiligung der Bürger an Projekten wird als wichtiger Punkt für die Nachhaltigkeit eines Projektes angesehen. Diese Beteiligung kann von freiwilligen Arbeitseinsätzen an Regierungsprojekten bis hin zu selbst verwalteten, autonomen Projekten gehen. Man unterscheidet vier Stufen:

- Informierung der Bevölkerung
- Beratung mit der Bevölkerung
- Beteiligung der Bevölkerung am Projekt
- Übertragung von Kontroll- und Entscheidungsfunktionen an die Bevölkerung

Die Art der Beteiligung der lokalen Bevölkerung ist davon abhängig, ob ein Gemeinschaftssinn unter den ansässigen Bürgern herrscht. Dies ist vor allem in ländlichen Gebieten der Fall. Hier kennen sich die Leute und man muss oft zusammenarbeiten. In den peri-urbanen Gebieten der wuchernden Städte leben jedoch meist Menschen die einander nicht kennen und deren Gemeinsamkeit oft nur darin besteht, dass sie unter denselben, schwierigen Bedingungen leben müssen. Der Lebensstress dem die Menschen hier ausgesetzt sind kann jedoch auch zu verstärkter Zusammenarbeit führen und oft sind die Ärmsten unter ihnen auch diejenigen mit dem stärksten Zusammenhalt. Vielerorts bilden sich Nachbarschaftsgruppen und Initiativen um die Lebensbedingungen zu verbessern oder ein gemeinsames Ziel zu erreichen. Dies kann zum Beispiel die gemeinsame Anschaffung einer Maschine sein oder eine Aktion zur Säuberung der Nachbarschaft von Hausmüll. Meist lösen sich diese Gruppen jedoch nach der Erreichung eines gemeinsamen Zieles wieder auf. Ausnahmen sind größere gut organisierte Bürgerorganisationen, die ein längerfristiges (oft ökonomisches) Ziel erreichen wollen.

Man versucht seit den neunziger Jahren bei Entwicklungshilfeprojekten verstärkt auf den Willen und Fähigkeit zur Selbsthilfe und zur Selbstorganisation der Bürger zu setzen. Oftmals wird hierbei jedoch übersehen dass die lokale Bevölkerung keine homogene soziale Einheit ist. Geschlecht, Ethnie, Einkommen, Religion und Alter trennen die Menschen meist untereinander ab. Bei der Involvierung von Bürger-Gruppierungen sollte man beachten, dass primär jeder Beteiligte sein eigens Wohl im Sinn hat und selten das Allgemeinwohl die treibende Kraft hinter Initiativen ist. Sieht der Einzelne jedoch einen Vorteil für sich, ist er oft dazu bereit, sich mit anderen zusammenzuschließen um wichtige Aufgaben zu übernehmen. Es hat sich gezeigt, dass Anlagen und Einrichtungen die unter Mithilfe der lokalen Bevölkerung errichtet wurden, ein Gefühl der Zuständigkeit erzeugen. Daraus resultierte eine höhere Bereitschaft diese Anlagen zu betreiben und zu warten.

Besonders für arme Zielgruppen, die täglich um die Sicherung ihres Lebensunterhaltes kämpfen, sind die Möglichkeiten und Spielräume für Selbsthilfe jedoch oft sehr eng. Ohne das entsprechende Umfeld sind Gemeinschaften nicht in der Lage signifikante Veränderungen herbeizuführen, beziehungsweise sich aktiv an Projekten zu beteiligen. Hierzu ist die Unterstützung kommunaler Behörden und eine finanzielle Mindestabsicherung nötig. Training in technischen Aspekten, Management und Finanzierung sind sehr wichtig soll die Bevölkerung für Teile der Sanitärversorgung zuständig sein.

Soziokulturelle Aspekte

Im Zusammenhang mit der Implementierung eines sanitären Konzeptes spielen soziokulturelle Aspekte eine wichtige Rolle. Vor allem im Betrieb von Systemen die auf die Behandlung und Wiederverwertung menschlicher Ausscheidungsprodukte abzielen können kulturelle, religiöse und geschlechterspezifische Verhaltens- und Denkmuster die Nachhaltigkeit erheblich beeinflussen. In vielen Kulturen ist die Wiederverwertung von Fäkalien und Urin ein Tabu. Dies spiegelt sich nicht nur in der Einstellung der Bevölkerung, sondern auch in der der Bürokraten, Planer und Ingenieure wieder, die oft voreingenommen sind. Soziale Faktoren prägen nachhaltig das Management und O&M bestimmter Systemteile und Anlagen. Diese müssen auch berücksichtigt werden.

Kulturelle Aspekte

Bei der Planung kreislauforientierter Sanitärsysteme müssen drei kulturelle Aspekte berücksichtigt werden:

- Psychologische Barrieren
- Geschlechtsspezifische Faktoren
- Der Einfluss der Religion

Es soll hierbei nicht weiter auf diese Punkte eingegangen werden, siehe hierzu die Diplomarbeit.

Eigentumsverhältnisse

Die Eigentums- oder Mietverhältnisse innerhalb der Nachbarschaften in den peri-urbanen Gebieten sind von hoher Wichtigkeit. Der Bau und Betrieb von Anlagen wird erheblich davon beeinflusst, ob die betroffenen Haushalte Eigentümer oder Mieter der Grundstücke sind. Erfahrungsgemäß besitzen die meisten Bewohner peri-urbaner Gebiete nicht den Grund auf dem sie Leben. Dies wirkt sich negativ auf die Bereitschaft aus, in Anlagen, deren Betrieb und deren Wartung zu investieren. Es muss daher eine Strategie eingeschlagen werden, die die Grundstückseigentümer mit in die Planung einbezieht.

Nachfrage

Der Bedarf/ die Nachfrage nach verbesserten sanitären Verhältnissen ist die Grundvoraussetzung für den Erfolg eines Projektes. Der Bedarf ist dafür verantwortlich wie stark sich die Nutzer dem System verpflichtet fühlen und wie groß ihr Wille ist, dieses zu erhalten. Oftmals wurde der Faktor Bedarf/ Nachfrage nicht in der Planung von Projekten berücksichtigt und Systeme zur Verfügung gestellt die von der Bevölkerung nicht gewünscht waren. Die Folgen waren schlecht gewartete oder sogar nicht benutzte Anlagen. Nachfrageorientierte Interventionen sind nachhaltiger als versorgungsorientierte Interventionen.

Hierzu ist es notwendig zu wissen was den Bedarf/die Nachfrage nach besseren sanitären Systemen motiviert. Es wurde lange davon ausgegangen, dass Menschen die in einer offensichtlich ungesunden Umgebung leben, sich sanitäre Anlagen zur Verbesserung der Hygiene und Gesundheit wünschen. Jedoch ist die treibende Kraft hinter der Nachfrage meist ein Wunsch nach Komfort, sozialem Status und Wahrung der Privatsphäre. Dies muss bei der Planung berücksichtigt werden und Investitionen sollten nur dann stattfinden, wenn Nachfrage vorhanden ist (diese kann auch stimuliert werden) und wenn die zugrunde liegenden Bedürfnisse berücksichtigt werden. Projekte zur Verbesserung sanitärer Verhältnisse sollten daher immer einen marktorientierten Weg einschlagen – Angebot und Nachfrage müssen zusammenpassen.

Aufklärung, Bildungsarbeit und Betreuung

Am Anfang jeden Projektes zur Einführung kreislauforientierter Sanitärkonzepte steht die Bewusstseinsbildung in der Bevölkerung und unter allen anderen Stakeholdern. Das Konzept muss verstanden und akzeptiert werden. Dies kann durch Bildungsarbeit mit bestimmten Zielgruppen erreicht werden, durch Einsatz von Massenmedien und durch Informationsveranstaltungen. Weiterhin müssen gewisse Verhaltensweisen angepasst werden, um neue Technologien und Prozesse zu betreiben. Auch während und nach der Implementierung muss weiterhin Betreuung und Unterstützung geleistet werden, um die Nachhaltigkeit zu gewährleisten.

Für O&M ist es besonders wichtig, dass konkrete Handlungsanweisungen vorliegen und laufende technische Unterstützung für die Nutzer und Betreiber gewährt werden kann. Einfach verständliche Handbücher für O&M sind ein guter Weg Verantwortliche gezielt mit Informationen zu versorgen. Angefangen von den Haushalten bis zu den

Kontrollorganen müssen alle betroffenen Personen in O&M unterwiesen und entsprechend ihrer Verantwortlichkeit geschult werden.

Technologische Aspekte

Die Auswahl der eingesetzten Technologien kann weit reichende Konsequenzen für die Nachhaltigkeit haben. Die Selektion ist ein planungsintensiver Prozess und muss auf einer fundierten Kenntnis der möglichen Technologien, ihren Kapital- und laufenden Kosten, sowie ihrem Betriebs- und Wartungsaufwand basieren. Die Bürger sollten hierbei immer miteinbezogen werden; sie müssen die Möglichkeit haben ihr bevorzugtes System mit auszuwählen – nach dem Prinzip von Angebot und Nachfrage. Hierfür müssen die Planer der Bevölkerung eine Auswahl von Technologien präsentieren, die zuvor auf Nachhaltigkeitskriterien geprüft wurden. Nachhaltigkeitskriterien für periurbane Gebiete sind zum Beispiel:

- Die Technologien dürfen nicht das Grundwasser verschmutzen,
- dürfen kein Wasser für den Transport von Exkrementen benötigen,
- müssen Exkremente hygienisieren und somit gewissen Gesundheitsanforderungen entsprechen,
- sollten niedrige Kapital- und Betriebskosten haben um finanziell nachhaltig zu sein.

Eine Vielzahl von Faktoren beeinflusst die Auswahl der Technologien auf der kommunalen Ebene. Dazu zählen technische Faktoren, Umweltfaktoren, Institutionelle Faktoren und sozial und kulturell beeinflusste gesellschaftliche Faktoren. Ein wichtiger technischer Faktor ist die Verfügbarkeit von Ersatzteilen. In Entwicklungsländern sind spezielle Ersatzteile oft schwer zu beschaffen und nicht selten führt dies zu Versorgungseinbrüchen oder Totalausfällen. Kann kein ausreichender Nachschub an Ersatzteilen gewährleistet werden, sollten Technologien, die keine speziellen Ersatzteile benötigen, bzw. deren Ersatzteile leicht von ansässigen Handwerksbetrieben angefertigt werden können, bevorzugt werden.

Management Optionen

Im Zusammenhang mit dezentralen Sanitärsystemen kann dezentrales Management sicherstellen, dass O&M von den lokalen Betreibern korrekt ausgetragen wird. Wie bereits erläutert, haben die Betreiber in diesem Fall einen direkten Bezug zu den betreffenden Systemteilen und man geht davon aus, dass dies das O&M verbessert. Dezentrales Management stellt jedoch nur dann eine Komplettlösung dar, wenn die Stoffströme auf dem lokalen Level recycelt werden können. Ist dies nicht der Fall, müssen Stoffströme exportiert werden und andere Stakeholder sind am Management beteiligt. In jedem Fall ist es nötig eine Kontrollinstanz auf dem Stadtlevel einzurichten die sicherstellt, dass alle Systeme den gesetzten Standards und Zielen entsprechend betrieben werden.

Die Zusammenarbeit verschiedenster Stakeholder und eine Auswahl an organisatorischen und finanziellen Strukturen sollte bei der Gestaltung von Betreibermodellen berücksichtigt werden.

Betrieb durch die Stadtverwaltung

Die direkte Erbringung von Dienstleistungen durch die Stadtverwaltung ist nur dann möglich, wenn sich bei einer öffentlichen Ausschreibung keine Betreiber finden, bzw. die städtische Behörde einen kostengünstigeren Betrieb anbieten kann. Wie bereits erwähnt, haben die meisten öffentlichen Behörden jedoch nicht die Kapazitäten und finanziellen Mittel, um vor allem in peri-urbanen Gebieten die benötigten Dienstleistungen zu erbringen. Der momentane Trend geht eher Richtung Beteiligung der Privatwirtschaft und Nutzerverbände.

Betrieb durch Nutzergemeinschaften

Das Management durch die Nutzer ist nur dann möglich, wenn geeignete Gruppen vorhanden sind, die entsprechende Fähigkeiten haben. Hierbei hat sich herausgestellt, dass ehrenamtliches Management auf die Dauer nicht funktioniert, es bedarf hierbei immer äußerer Anreize. Ein Problem hierbei stellen auch größere Reparaturen und Neuanschaffungen dar, da dazu oft vertragliche Bindungen nötig sind, die die Nutzer nicht eingehen wollen oder aus finanziellen Gründen auch nicht können. Grundvoraussetzungen für das Funktionieren dieses Modells sind unter anderem:

- Ein Gefühl der Eigentümerschaft
- Bedarf/ Nachfrage
- Beteiligung der Nutzer am Planungsprozess
- Kontinuierliche Unterstützung von Außen
- Klares Verständnis der Rollen und Zuständigkeiten

Oft wird technischen Fragen mehr Bedeutung zugemessen als den Fähigkeiten im Management und in finanziellen Angelegenheiten. Diese Fähigkeiten sind jedoch essentiell und müssen vorhanden sein beziehungsweise erworben werden. Bevor Aufgaben und Zuständigkeiten an Nutzergemeinschaften übertragen werden können, bedarf es einer Analyse und Beurteilung der vorhandenen Fähigkeiten der Nutzer.

Privatwirtschaftliches Management

Die Einbindung der Privatwirtschaft in öffentliche Dienstleistungen hat, vor allem in den Großstädten der Entwicklungsländer, in letzter Zeit erheblich an Bedeutung gewonnen. Eher selten werden hierbei staatliche Betriebe/ Dienstleistungen vollständig privatisiert. Meist operieren private Firmen unter zeitlich befristeten Verträgen.

In Afrikas Städten spielt der Privatsektor bereits eine erhebliche Rolle im Stoffstrommanagement. Mittelständische Dienstleister errichten sanitäre Anlagen und entschlammen diese, sie errichten und betreiben öffentliche Toiletten und engagieren sich in der Abfallsammlung und im Recycling. Diese Art von Kleinunternehmen (wenige

Mitarbeiter, niedriges Kapital und unregelmäßige Einnahmen) werden aufgrund ihres hohen Verbreitungsgrades und ihrer hohen Flexibilität auch in kreislauforientierten Konzepten eine Rolle spielen. Für den Betrieb von übergeordneten sanitären Systemen bedarf es aber meist größerer Unternehmen.

Public-Private-Partnerships (PPP)

Eine allgemeingültige Begriffsdefinition des PPP gibt es nicht. Es handelt sich im weitesten Sinne um die Kooperation staatlicher Stellen und privatwirtschaftlicher Unternehmen bei der Planung, Erstellung, Finanzierung, Erbringung bislang staatlich erbrachter öffentlicher Leistungen (oder bei dem Betrieb solcher Einrichtungen). Typischerweise überträgt die öffentliche Hand von ihr zu erbringende Leistungen auf ein Privatunternehmen. Die öffentliche Hand erwartet sich von PPPs die Entlastung der angespannten öffentlichen Haushalte, da der private Unternehmer die gesamte Finanzierung maßgeblich, abgestellt auf die Wirtschaftlichkeit des Projektes, selbst besorgt.

Traditionellerweise sind PPPs im Abwasserbereich wenig zu finden. Dies hängt vor allem mit den geringen Profitmöglichkeiten des Sektors zusammen. Jedoch könnten kreislauforientierte Sanitärkonzepte hier eine Ausnahme bilden. Vorteile sind zum Beispiel die niedrigeren Kosten für Infrastruktur (Kanäle sind nicht nötig), außerdem könnte der Wert kommerziell nutzbarer Stoffe aus dem Recyclingprozess zusätzliche Anreize schaffen. Arten des PPP sind zum Beispiel:

- Betriebsführungsmodelle (Die öffentliche Hand bleibt Eigentümer und Betreiber; das Unternehmen betreibt gegen Bezahlung auf vertraglicher Basis Anlagen/ Systeme für eine bestimmte Laufzeit; es gibt verschiedene Modelle, jedoch ist O&M immer Zuständigkeit des Unternehmens)
- Konzessionsmodelle (hierbei hat das Unternehmen volle Verantwortung für die Erbringung der Dienstleistung(en), für O&M und für die Finanzierung durch Gebühren; die öffentliche Hand bleibt Eigentümer der Anlagen/Systeme und hat Kontrollfunktionen)
- BOT-Modelle (BOT = Build-Operate-Transfer, deutsch: Bauen, Betreiben, Übertragen)
- BOO-Modelle (BOO = Build-Own-Operate, deutsch: Bauen, Besitzen, Betreiben)
- BOOT-Modelle (BOOT = Build-Own-Operate Transfer, deutsch: Bauen, Besitzen, Betreiben, Übertragen)

Kostendeckung

‚Zu wenig Geld' wird oft als Hauptgrund für fehlende Entsorgungsdienstleistungen angegeben. In vielen Fällen sind aber nicht nur der Mangel an Geld, sondern auch schlechtes finanzielles Management und geringe Zahlungsbereitschaft Mitverursacher des Problems. Je finanziell unabhängiger von staatlichen Geldern ein System betrieben werden kann, desto höher ist die Wahrscheinlichkeit, dass es für längere Zeit funktioniert. Verbrauchergebühren werden als zentrales Element für die Nachhaltigkeit angesehen und es sollten zumindest die Betriebskosten durch Gebühreneinnahmen gedeckt werden, will man finanziell nachhaltig wirtschaften. Größere Reparaturen und Systemerweiterungen können meist nicht über die Gebühreneinnahmen gedeckt werden. Daher ist es wichtig von vorneherein in der Planung alternative Finanzquellen ausfindig zu machen und deren Verfügbarkeit zu prüfen. Auch nicht-finanzielle Beiträge zu O&M können einen wichtigen Teil der Kostendeckung ausmachen. Die Bereitstellung von Arbeitskraft und lokalen Materialien sind ein häufiger Bestandteil in Projekten, welche unter der Beteiligung der lokalen Bevölkerung stattfinden.

Finanzieller Hintergrund zu Ecosan

Kreislauforientierte Sanitärsysteme haben grundsätzlich eine andere Kostenstruktur als herkömmliche Abwassersysteme. Die Investitions- und Betriebskosten sind meist geringer als bei konventionellen (kanalisierten) Systemen. Dies hängt mit der dezentralen Natur der Anlagen zusammen – teure Infrastruktur wie Kläranlagen, Kanalisation und Pumpanlagen fallen weg. Im Vergleich mit gewöhnlichen Latrinen, die meist neu errichtet werden müssen, sobald die Fäkaliengruben angefüllt sind, stellen kreislauforientierte Anlagen permanentere Lösungen dar und kosten auf ihre Lebenszeit gerechnet dadurch weniger.

Es muss berücksichtigt werden, dass kreislauforientierte Systeme im städtischen Bereich, bedingt durch die Notwendigkeit einer städtischen Sammlung, Transport und Behandlung, grundsätzlich um einiges teurer sind als im ländlichen Bereich. Zusätzlich fallen bei kreislauforientierten Konzepten immer Kosten für die Aufklärungs-, Informations- und Ausbildungsaktivitäten an. Auf der anderen Seite könnte der Verkauf recycelter Produkte die Gesamtkosten wiederum reduzieren.

Kostenvergleiche verschiedener sanitärer Konzepte werden zwar von einigen Autoren erstellt, jedoch ist hierbei die Vergleichbarkeit der Ergebnisse untereinander nicht möglich. Jeder Autor setzt die Grenzen seiner Bilanzierung anders und somit werden auch oft verschiedene Komponenten berücksichtigt. Selten werden externe Kosten (also Kosten die aufgrund der Schädigung von Mensch und Umwelt entstehen) miteinbezogen und die schlechte Datenbasis für die Betriebskosten kreislauforientierter Systeme im urbanen Bereich führt zusätzlich zu Ungenauigkeiten. Grundsätzlich kann festgestellt werden, dass Sammlung und Transport bei kreislauforientierten Systemen den größten Anteil an den Betriebskosten darstellen. Insbesondere stellen hierbei die Sammlung, der Transport und die Lagerung großer Mengen an Urin eine Herausforderung dar.

Zahlungsfähigkeit und Zahlungsbereitschaft

Die Zahlungsfähigkeit und die Zahlungsbereitschaft der Nutzer sind wichtige Voraussetzungen für die Finanzierbarkeit von O&M. Für die Zahlungsfähigkeit besagt ein Richtwert, dass nicht mehr als 3-5 % des Gesamteinkommens für Trinkwasser und Entsorgungsleistungen aufgebracht werden sollten. In verarmten Gegenden wird dieser Wert jedoch oft überschritten und mancherorts müssen die Menschen mehr als 20 % ihres Einkommens für die genannten Leistungen opfern.

Fast die Hälfte aller Bewohner Afrikas südlich der Sahara leben von weniger als US$ 1 am Tag. Wendet man die 3-5 % Regel hierauf an, ergibt sich ein Jahresbudget für Trinkwasser und Entsorgungsleistungen von US$ 18 pro Person. Für die 50 % die unter dieser Grenze leben sind US$ 10 im Jahr meist schon zu viel. Da Trinkwasser, vor allem in den Randbezirken von Städten, oft nicht über Hausanschlüsse zu beziehen ist, muss es für einen höheren Preis von lokalen Wasserhändlern gekauft werden. Es bleibt folglich kaum Geld übrig, um es in Abfallentsorgung oder sanitäre Systeme zu investieren. Ein Projekt zur Verbesserung der sanitären Situation sollte daher idealer weise mit der Bereitstellung einer erschwinglichen Trinkwasserversorgung einhergehen.

Der Zahlungswille der lokalen Bevölkerung ist ein Ausdruck von Bedarf oder Nachfrage nach der erbrachten Leistung. Der Zahlungswille wird von vielen Faktoren beeinflusst. Zum Beispiel von:

- Qualität der erbrachten Dienstleistung
- Wahrgenommener Nutzen daraus
- Einkommen
- Preis
- Vorhandene sanitäre Situation
- Ruf/ Ansehen des Dienstleister
- Zusammenhalt der lokalen Bevölkerung
- Institutionelle und gesetzliche Rahmenbedingungen
- Soziokulturelle Faktoren
- Gefühl von Eigentum und Verantwortung für das System

Manche dieser Faktoren können auch gezielt optimiert werden um den Zahlungswillen zu heben. Der Zahlungswille muss in die Planung einfließen und kann auf verschiedene Arten erfasst werden. Es gibt Methoden zur direkten und indirekten Erfassung und die Möglichkeit hypothetischer und echter Verhaltensstudien. Siehe die Diplomarbeit für nähere Erläuterungen.

Ermittlung der Betriebskosten

Im Vergleich zu Kapitalkosten sind die Betriebskosten grundsätzlich schwieriger zu ermitteln, da sie von einer Vielzahl von Faktoren beeinflusst werden. Systeme gleicher Bauart können unter verschiedenen Rahmenbedingungen sehr unterschiedliche Betriebskosten aufweisen. Ein Rückgriff auf verlässliche Erfahrungswerte und ein Vergleich von Projekten in verschiedenen Ländern oder Regionen ist daher kaum möglich. Es gibt verschiedene Arten um Betriebskosten zu ermitteln; hierbei unterscheidet man zwischen den Posten die mit einberechnet werden. Typische Betriebskosten (Kosten für Betrieb und Unterhaltung) sind beispielsweise:

- Material- und Verbrauchsstoffe;
- Ersatzteile und Ausrüstungsgüter;
- Personalkosten für Betrieb und Unterhaltung der Einrichtungen;
- Verwaltungs- und Managementkosten;
- Energiekosten;
- Kosten für Reparaturen und Ersatzinvestitionen;
- Unterstützungskosten und externe Leistungen (z.B. für Beratungsleistungen);
- kalkulatorische Abschreibungen;
- Finanzierungskosten (z.B. Zinsaufwand bei Kreditfinanzierung, sonstige Kapitalkosten)

Die Gebührengestaltung

Gebühren müssen sozial gerecht sein und finanzielle Nachhaltigkeit gewährleisten. Die Art und Höhe der Gebühren muss so festgelegt werden, dass es auch den Armen möglich ist, diese zu bezahlen. Deren niedriges Einkommen ist meist unregelmäßiger Natur und die Gebührengestaltung muss dementsprechend angepasst werden. Andererseits müssen die Gebühren auch die Kosten widerspiegeln, um zumindest für laufende Kosten aufkommen zu können. Niedrige Gebühren können auch zu mehr negativen Umweltauswirkungen führen, da zum Beispiel im Falle einer sehr niedrigen Abwassergebühr, mehr Abwasser eingeleitet werden würde als bei höheren Gebühren. Quersubventionierung stellt eine Möglichkeit dar die Gebühren dem jeweiligen Einkommen anzupassen. Es gibt eine Auswahl an Gebührenarten die vor allem aus dem Trinkwasser und Abfall-Bereich stammen. Diese haben verschiedene Anwendungsgebiete und können den Gegebenheiten entsprechend eingesetzt werden. Für genauere Erläuterungen - siehe Diplomarbeit.

Finanzmanagement

Die Anforderungen an das Finanzmanagement von Entsorgungssystemen hängen in erster Linie von der Komplexität des jeweiligen Betriebs- und Organisationsmodells ab. Grundsätzliche Aufgaben, die für alle Betriebsformen in ähnlicher Weise, aber in unterschiedlichem Umfang erforderlich sind, lassen sich den folgenden Bereichen zuordnen:

- Haushaltplanung und -führung;
- Rechnungswesen und Inkasso;
- Buchhaltung,
- Kontrolle und Monitoring.

Je nach Betriebsmodell müssen diese weiter differenziert werden. Abhängig davon müssen geeignete Organisationsstrukturen mit entsprechend qualifiziertem Personal aufgebaut werden.

Alternative Finanzierungsmöglichkeiten

Angesichts des großen Bedarfs für eine bessere Entsorgung und Hygiene in periurbanen Gebieten, sowie der nur selten möglichen Deckung aller Kosten durch Gebühren ist der Zugang zu alternativen Finanzierungsmöglichkeiten eminent wichtig. Neben der Erhebung von Gebühren gibt es eine Reihe weiterer Möglichkeiten, die notwendigen Investitionen und Reparaturen und mit Einschränkungen auch den Betrieb (zeitlich beschränkt) zu finanzieren.

Gebergelder und Entwicklungsfonds

Projekte auf dem Gebiet von Entsorgungsleistungen und öffentlicher Hygiene in städtischen Armutssiedlungen werden vielfach über Zuschüsse oder Kredite von externen bi- oder multilateralen Geberinstitutionen finanziert. Die Unterstützung erfolgt dabei überwiegend projektbezogen oder im Rahmen von breiter angelegten Förderprogrammen. Zuschüsse oder zinsvergünstigte Kredite werden größtenteils für die Finanzierung der Investitionskosten sowie für begleitende Beratungsleistungen eingesetzt. Eine Bezuschussung oder Finanzierung der Betriebskosten erfolgt dagegen nur in Ausnahmefällen und zeitlich begrenzt für Wartungs- und Instandhaltungsaufgaben. Für den längerfristigen Betrieb wird meist eine frühzeitige Übernahme der Verantwortung durch einen geeigneten Betreiber und eine Deckung der Betriebskosten durch Gebühren angestrebt.

Zuschüsse und Subventionen

Kommunale oder staatliche Zuschüsse sind eine weitere Möglichkeit der Finanzierung von Investitions- und Betriebskosten. Sie können entweder aus den regulären Haushalten der zuständigen Institutionen oder aus speziellen Förderprogrammen/–budgets bestritten werden. Staatliche und kommunale Haushaltsmittel werden häufig für die Finanzierung der laufenden Betriebskosten, vor allem der Personalkosten, von öffentlichen Trägern eingesetzt, die nur selten kostendeckende Gebühren erheben.

Wie bereits erwähnt, sollten die Gebühren grundsätzlich zumindest die Betriebskosten decken und dementsprechend gestaltet werden. Es gibt mehrere Ansätze, um verfügbare Zuschüsse (direkt oder indirekt) denjenigen zukommen zu lassen, die anderweitig keine finanziellen Möglichkeiten hätten, die Entsorgungsleistungen in Anspruch zu nehmen. Zum Beispiel:

- Direkte Zuschüsse
- Quersubventionierung
- Ergebnisabhängige Zuschüsse (‚Output-based-aid')
- Für genauere Erläuterungen siehe Diplomarbeit.
- Nutzerbeiträge und Eigenleistungen

Einmalige Beiträge der Nutzer von Entsorgungsleistungen kommen vor allem für die Finanzierung der haushalts- oder grundstücksbezogenen Investitionen in Betracht (beispielsweise den Bau einer Dehydrierungstoilette). Darüber hinaus sind auch allgemeine Beiträge zu den Kosten von Entsorgungsmaßnahmen für den gesamten Stadtteil möglich, sofern die Zielgruppen hierzu bereit und fähig sind. Solche Beiträge können grundsätzlich sowohl finanzieller Natur wie auch in Form von Eigenleistungen erbracht werden. Eigenleistungen der Nutzer für den Betrieb der Einrichtungen/ Systeme - etwa für Wartungs- und Instandhaltungsarbeiten oder die Sammlung und Verwaltung von Gebühren - können ebenfalls zu einer Kostenreduzierung beitragen. In allen Fällen müssen diese Nutzerbeiträge sorgfältig auf die Interessen und Möglichkeiten der Zielgruppe abgestimmt werden.

Eine Alternative zu einmaligen finanziellen Leistungen stellen gemeinschaftliche Geldanlagen dar, welche vor allem aus Trinkwasserversorgungs-Projekten bekannt sind. Es gibt hierbei verschiedene Sparmodelle für Gruppen von Nutzern die gemeinsam einen kommunalen Fond einrichten, um daraus Investitionen tätigen zu können.

Mikrokredite

Mikrokredite sind grundsätzlich vergleichbar mit ‚normalen' Krediten, welche für gewöhnlich von Banken und anderen Finanzinstitutionen ausgegeben werden. Sie unterscheiden sich lediglich in ihrem Umfang – es sind Kleinkredite und Kleinstkredite. Sie bieten auch den Armen Zugang zu finanziellen Dienstleistungen, die bisher für sie verwehrt geblieben sind. Hierbei unterscheidet man drei Arten von Kreditgebern:

- Banken
- Genossenschaften/ Verbände
- Einzelpersonen

Mikrokrediten wird ein hoher Stellenwert in der Bekämpfung der Armut beigemessen, bieten sie doch den Ärmsten die Möglichkeit Investitionen zu tätigen, um sich beispielsweise eine unternehmerische Existenz aufzubauen. Mikrokredite sind gerade in Armutssiedlungen wichtige Instrumente zur Finanzierung von Entsorgungsmaßnahmen. Dabei sind drei unterschiedliche Formen von Krediten zu unterscheiden:

- Kredite an Haushalte oder Nutzer
- Kredite an Gemeinschaftsprojekte
- Kredite an lokale Kleinunternehmer

Diese Mikrokredite können in Entsorgungsprojekten verschiedene Zwecke erfüllen, zum Beispiel:

- Als Beitrag zu größeren Investitionen
- Zum Kauf von Material und Ausrüstung für Ersetzungen, Erweiterungen und Rehabilitationen
- Zur Finanzierung unvorhergesehener größerer Reparaturen
- Zur Beseitigung kurzfristiger Liquiditätsprobleme

- Zum Aufbau eines Vorrat an Reserveteilen, Werkzeugen und Ausrüstungsgegenständen

Public-Private-Partnerships

Es gibt eine Vielzahl an Möglichkeiten für eine Zusammenarbeit und ein Zusammenwirken zwischen öffentlichen und privaten Partnern bei der Finanzierung von Investitionen und beim Betrieb von Entsorgungsmaßnahmen. Von der Miteinbeziehung des privaten Sektors sollte jedoch nicht erwartet werden, dass dies öffentliche Investitionen ersetzen könnte oder gar Behörden aus ihren Verantwortlichkeiten entlassen würde. Im Allgemeinen sind private Unternehmen am besten in der Lage Kosten zu verringern und Standards zu verbessern, wenn:

- flexible Verträge mit langen Laufzeiten für große Bereiche und breite Dienstleistungspaletten angeboten werden können
- die erwarteten Ziele verbindlich festgelegt werden, jedoch ohne strikte Vorgaben für den Weg zur Erreichung dieser Ziele.

Der Gebrauch ergebnisabhängiger Vereinbarungen ist hierbei besonders zu empfehlen. Das Engagement privater Unternehmen in besonders armen Gegenden ist besonders problematisch, da hier die Chance auf Kostendeckung meist gering ist, beziehungsweise dies die allgemeine Ansicht ist. Durch geeignete finanzielle Strukturierung unter Beihilfe verschiedener finanzieller Mechanismen und Risikominimierungsmittel kann jedoch, wenn das Umfeld dies begünstigt; auch in Armutsvierteln nachhaltig gewirtschaftet werden. In der Diplomarbeit werden geeignete Richtlinien kurz vorgestellt.

Fallstudie

Einleitung

Im Anschluss an die Literaturstudie konnte während eines zweiwöchigen Aufenthalts in Nakuru, Kenia noch eine Fallstudie zum Thema O&M von Entsorgungsleistungen erstellt werden. Nakuru ist eine der vier ostafrikanischen Partnerstädte im ROSA Konsortium und wird im Laufe des Projektes mit einem kreislauforientierten Sanitärsystem auf Pilot- beziehungsweise Demonstrationsebene ausgestattet werden. Weiterhin wird für ganz Nakuru ein strategischer Entsorgungsplan erstellt werden, welcher als Grundlage für weitere Verbesserungen auf dem Abfall und Hygienegebiet dienen soll.

Hintergrund

Nakuru ist die viertgrößte Stadt in Kenia und hat geschätzte 500.000 Einwohner. Die Bevölkerung wächst rapide mit einer Rate von jährlich circa 5,6 %. Nakuru liegt eingeklemmt zwischen dem beeindruckenden Menengai Vulkankrater und dem, für seine Flamingos weltberühmten Lake Nakuru Nationalpark.

Bedingt durch das schnelle Bevölkerungswachstum, die geographische Lage und der schlechten wirtschaftlichen Situation Kenias (oder Afrikas), ist Nakuru mit erheblichen Umweltproblemen und Versorgungsdefiziten konfrontiert. Ein großer Teil der Bevölkerung lebt in den peri-urbanen Gebieten unter schwierigsten Verhältnissen. Die Wasser-versorgung ist schlecht, Müll verschmutzt die Nachbarschaften und die sanitären Anlagen sind unzureichend, um nur einige Probleme zu nennen.

Die Stadt wurde als Ort für die Fallstudie ausgewählt, da sie ein direkter Partner von Ecosan Club Austria, für die diese Arbeit erstellt wurde; im ROSA Projekt ist. Des weiteren bot sich Nakuru durch starke Aktivitäten im Umweltbereich (unter Mitwirkung verschiedenster Stakeholder) gut für eine Studie an.

Zielsetzung

Ziel der Studie war es, folgende Fragestellungen zu bearbeiten:

- Welche Stakeholder sind am Betrieb dieser beteiligt und verantwortlich?
- Was sind die Hauptprobleme der Entsorgungsdienstleistungen in Nakuru, Kenia?
- Wie gut eignet sich die vorhandene Kompostierungsanlage für eine Co-Kompostierung von Bioabfall mit Exkrementen?

Hierbei standen die Abfallentsorgung im Mittelpunkt der Untersuchung, weil diese dem Prinzip der kreislauforientierten Sanitärkonzepte noch am ehesten entspricht:

- Hausmüll wird als eine Ressource angesehen, bis auf Plastiktüten und Bioabfall wird fast alles recycelt.
- Abwasser und Fäkalschlämme werden nicht wiederverwertet, sondern landen über den Umweg der städtischen Kläranlage im See.

Eine örtliche Kompostierungsanlage auf der Mülldeponie und ein Hersteller für organischen Dünger wurden aufgesucht, um die Fragestellung nach den Möglichkeiten einer Co-Kompostierung zu erörtern. Des Weiteren wurden noch die peri-urbanen Gebiete und ein Fahrzeuglager der städtischen Betriebe einer Visite unterzogen.

Aufgrund des beschränkten Zeitrahmens konnte keine detaillierte Fallstudie, z.B. mit statistischen Erhebungen, erstellt werden. Durch Gespräche und Interviews mit verschiedenen Stakeholdern konnte jedoch ein genereller Überblick über die Situation der Entsorgungsleistungen erreicht werden.

Ergebnisse

Im Folgenden werden kurz die Ergebnisse der Fallstudie präsentiert. Für detaillierte Informationen zur Fallstudie, siehe Diplomarbeit.

Abfallmanagement

Die peri-urbanen Gebiete sind übersät von Plastiktüten und sonstigem Müll. Verantwortlich für das Abfallmanagement ist eigentlich die Stadtverwaltung, welche bedingt durch die schwache Finanzlage große Teile der peri-urbanen Gebiete nicht versorgen kann. Es wird versucht Privatunternehmen und Nutzergruppen zu involvieren und das ganze Stadtgebiet wurde in drei verschiedene Zonen, entsprechend diesen drei Dienstleistern, unterteilt. Jedoch finden sich kaum freiwillige Nutzergruppen – Kostendeckung ist kaum möglich, da die Bewohner der peri-urbanen Gebiete nicht bezahlen wollen und ohne entsprechende Zuschüsse ist der Erwerb von Ausrüstung kaum möglich. Nutzergruppen müssen sogar eine ‚Registrierungsgebühr' an die Stadtverwaltung bezahlen, um im Abfallmanagement tätig zu werden. Private Betreiber sind nur in den Gegenden aktiv, in denen die Bewohner bereit sind, für Abfallsammlung zu bezahlen. Noch im April 2007 wurde eine neue Verordnung erlassen, die es für jeden Haushalt zur Pflicht macht bei einem Dienstleister einen Vertrag für Abfallsammlung zu unterschreiben und regelmäßig zu bezahlen. Die Durchsetzung dieser Verordnung wird jedoch den Dienstleistern zugeschoben und dürfte sich als äußerst schwierig erweisen.

Vom WWF wurden 14 Müllsammelstellen in den peri-urbanen Gebieten eingerichtet, von denen die meisten nicht mehr betrieben werden. Die italienische Regierung hat 1998 Sammelfahrzeuge und Container zur Verfügung gestellt – ein Großteil dieser Ausrüstung verrostet momentan im städtischen Fahrzeigdepot, da keine Ersatzteile für die Reparatur der Fahrzeuge besorgt werden konnten.

In Nakuru hat sich kürzlich ein Umweltkonsortium gebildet. In diesem Konsortium sitzen die Stadtverwaltung, einige größere Nutzergruppen, NGOs und die lokale Universität. Gemeinsam will man, unter der Leitung einer sehr aktiven NGO, gegen die Umweltprobleme vorgehen.

Co-Kompostierung

Für die Co-Kompostierung wurden vier mögliche Szenarien erwägt:

A. Co-Kompostierung von Fäkalschlamm und Bioabfall in der Kompostierungsanlage

B. Co-Kompostierung von getrockneten Fäkalien aus Dehydrierungstoiletten und Bioabfall in der Kompostierungsanlage

C. Zugabe von Urin zum Kompostierprozess in der Kompostierungsanlage

D. Zugabe von Urin in der Düngemittelherstellung

Szenario A bedarf größerer Investitionen – es wäre eine komplett neue Anlage nötig, um die Co-Kompostierung mit Fäkalschlamm zu ermöglichen. Die Organisation des Betriebes müsste auch grundlegend geändert werden, um Nachhaltigkeit zu erzielen.

Szenario B wäre weniger kapitalintensiv, aber es wären immer noch größere Investitionen nötig. Auch hier müsste der Betrieb auf professioneller Ebene organisiert werden, um Umwelt und Qualitätsstandards zu entsprechen.

Szenario C erwies sich unter den gegebenen Vorraussetzungen als billigste Variante und könnte durch die Steigerung der Kompostqualität positive Auswirkungen auf die Bezahlung der MEWAREMA Gruppe haben.

Szenario D scheint nach einer einfachen Bilanzierung der benötigten Nährstoffmengen unrealistisch zu sein. Zu große Mengen an Urin wären nötig, um den gewünschten Nährstoffgehalt des organischen Düngers zu erreichen.

Diskussion

In der Diskussion wird noch einmal kurz auf die wichtigsten Ergebnisse der Literaturstudie und der Fallstudie eingegangen, siehe hierzu die Diskussion in der Diplomarbeit. Zur Richtigkeit und Vollständigkeit der gegebenen Informationen ist noch anzumerken dass:

- In der Literaturstudie nicht alle relevanten Dokumente ausfindig gemacht und ausgewertet werden konnten, aufgrund der breiten Thematik.
- Die Aussagen der interviewten Personen in Nakuru immer auch eine persönliche Meinung widerspiegeln und somit Unrichtigkeiten übernommen worden sein könnten.

Anhand der gesammelten Informationen und Erfahrungen werden noch Empfehlungen gegeben. Allgemeine Empfehlungen sind:

- Das Bewusstsein für die Wichtigkeit und die Aspekte von O&M muss für alle Projektpartner/ Stakeholder geschaffen werden.
- Zusammenarbeit und Kommunikation müssen effektiv koordiniert werden, besonders in Hinsicht auf die Beteiligung vieler Partner am Projekt
- Wissenstransfer von Personen/ -institutionen auf andere Stakeholder ist wichtig in O&M. Besonders wichtig ist der Transfer von Wissen, wenn eine Schlüsselperson das Konsortium/ die Organisation die für O&M zuständig ist verlässt.
- Es sollte bei einer Intervention immer erst das O&M der bestehenden Systeme optimiert werden, bevor neue Systeme installiert werden. Dies führt meist schneller und nachhaltiger zu Verbesserungen der Situation.
- Peri-urbane Landwirtschaft, welche häufig vorhanden ist, sollte in die Planung eines kreislauforientierten Sanitärkonzeptes integriert werden. Somit können lokal Stoffkreisläufe geschlossen werden.

Spezielle Empfehlungen für Nakuru sind:

- Gesammelter Urin aus Separationstoiletten sollte im Kompostierprozess verwendet werden, um die Kompostqualität zu steigern (und um den Kompostierprozess zu beschleunigen/ höhere Temperaturen zu erreichen).
- Die Beteiligung der Bevölkerung an Entsorgungsdienstleistungen sollte von Seiten der Stadtbehörde nur mehr stimuliert werden, wenn konkrete Unterstützung und finanzielle Mittel zur Verfügung gestellt werden können.
- Für Nakuru wird ein genossenschaftliches Betreibermodell (für den Fall eines stadtweiten kreislauforientierten Sanitärsystems) vorgeschlagen, bei dem alle Partner des Umweltkonsortiums mitwirken können.

In einigen Gebieten besteht noch Forschungsbedarf:

- Es gibt wenig Erfahrung wie man peri-urbane Landwirtschaft mit kreislauforientierten Sanitärkonzepten verbinden könnte.
- Hinsichtlich dezentraler Managementsysteme für kreislauforientierte Sanitärsysteme existiert wenig Wissen
- Über die Wartungs- und Betriebsansprüche kreislauforientierte Sanitärsysteme, insbesondere für die Sammlung, den Transport und die Behandlung von Stoffströmen gibt es kaum Informationen.

Großangelegte Urinsammlung, Transport und Speicherung stellen eine große finanzielle Belastung für Entwicklungsländer dar. Hier besteht noch Bedarf an der Erforschung alternativer Methoden und Techniken.

Abstract

Many projects aiming to improve environmental services in developing countries, although providing adequate infrastructure facilities, fail in the long run because of problems with operation and maintenance (O&M). This document deals with the issue of sustainable O&M of resource-oriented sanitation systems in peri-urban areas of developing countries. It consists to the largest part of a literature survey followed by a short case study.

The literature survey aims to identify the necessary framework conditions for sustainable O&M in the urban/ peri-urban context. The Ecological Sanitation (Ecosan) concept and some technologies frequently applied in this approach, as well as characteristics of different waste-flows, treatment processes and system properties are described to provide a background for O&M of resource-oriented sanitation systems. For O&M it has been found that project planning has to consider a variety of environmental, legal, institutional, socio-cultural, financial and technical factors and processes. These factors and processes and the way they could impact on sustainability are highlighted. Furthermore various management and partnership options for O&M of the sanitation systems are described and relevant stakeholders and their possible roles in management and O&M detailed. Management by user associations, the municipality and the private-sector, as well as hybrid forms can be possible solutions, depending on the local context. Financial characteristics of Ecosan, financing methods and alternative financial resources for cost recovery are finally discussed. The importance to recover O&M costs mainly through user fees and the necessity to still plan for alternative sources of finance are highlighted and alternative financial sources identified.

The case study was conducted during two weeks in April 2007 in Nakuru, Kenya, a fast growing town with currently around 500.000 inhabitants. By observation and interviews with local stakeholders, basic problems in O&M of waste services are identified. The weak financial resource base of the municipality leaves large areas of the town without environmental services. The involvement of user groups and the private-sector in waste management, although seen as a way out of the crisis, seems to be constrained by poor cost recovery chances in the peri-urban areas and by a non supportive context. Waste management equipment donated to the municipality by a foreign government is not in use anymore due to problems with O&M. The possibility for co-composting of human excreta and biological solid waste in the Nakuru composting activities is assessed. It is found that the current composting scheme would only allow for the use of collected urine in the composting process without the need for larger investments. Other co-composting scenarios are either not feasible or would need for large investments in new composting plants.

1 Introduction

1.1 Background

According to the United Nations, in 2007 for the first time in human history, more than half of the world's residents will be living in cities. "We are entering the "Urban Millennium" (Gündel 2006). With an extraordinary pace these cities are growing, especially in low- and middle-income countries, where urban population is said to double in less than 30 years. The migration to cities often results in informal settlements (slums, squatter camps, peri-urban areas[7]), where infrastructure, waste management and sanitation facilities are usually of secondary importance to the inhabitants, during the initial phases of settlement. The limited infrastructure facilities that are provided are often inadequate and the result is a deteriorating environment (Parkinson, Tayler 2003).

Four out of every ten people in the world do not have access to even a simple pit latrine and nearly two in ten have no source of safe drinking water (Bartram et al. 2005). The consequences are, among others, diarrhoeal diseases, which are killing about 4,900 young children each day. Close to half of all people in developing countries are suffering at any given time from a health problem caused by water and sanitation deficits (UNDP 2006). Poverty, sanitation and illness are closely linked together, and like so often, the poor and especially women and children are the ones suffering most.

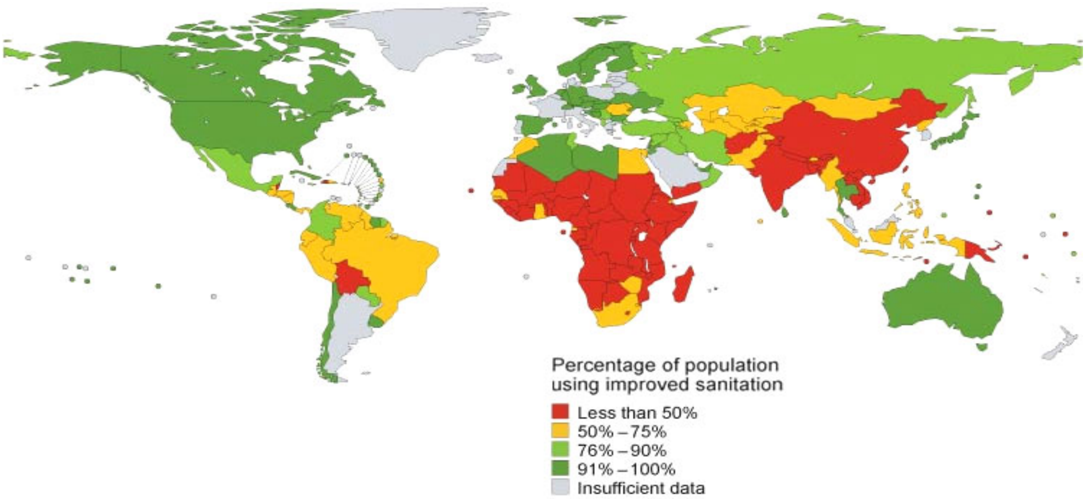

Figure 1: Sanitation coverage in 2002[8]

[7] The term 'peri-urban area' cannot be easily defined. It is a name given to the grey area which is neither entirely urban nor purely rural. In this thesis it refers to the low-income urban fringe area which is characterised by fast growth and low environmental service coverage.

[8] Source: www.unicef.org, [Online; 01.03.2007]

Figure 1 shows the world with regard to the sanitation crisis. About 2.6 billion people worldwide do not have access to improved sanitation[9] and 1.1 billion do not have access to clean water (UNDP 2006).

The Millennium Development Goals (MDGs) set by world leaders at the Millennium Summit in September 2000 “aim to reduce poverty and improve lives”. The headline of Goal No. 7, “Ensure Environmental Sustainability”, sets the target to “halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation” (UNDG 2007). Subsequently the U.N. General Assembly has declared 2008 the International Year of Sanitation[10], to boost efforts for reaching the sanitation goal.

Sub-Saharan Africa is making the slowest progress towards achievement of the MDG goals on water and sanitation. Sub-Saharan Africa hosts the largest proportion of the urban population residing in slums (71.9 %); 166 million out of the total urban population of 231 million are classified as slum dwellers (Gündel 2006). In Africa roughly 60% of the urban population is without adequate sanitation (UN Millennium Project 2005).

In most African countries, among other reasons, the lack of financial capacity and water scarcity hamper the implementation of conventional sanitation (end-of-pipe technologies). Existing solutions based on on-site storage of human excreta often are inadequate as they pollute groundwater and emptying and indiscriminate dumping of the faecal sludge (FS) poses a health risk. Innovative low-cost technologies have to be applied to fulfil the MDGs target on sanitation. As the depletion of soil fertility and the need to increase agricultural production are urgent problems in Africa, approaches aiming at conserving and recycling nutrients from human excreta to soil are desirable.

In October 2006 the three year project ‘Resource-oriented sanitation concepts for peri-urban areas in Africa’ (ROSA) under the Sixth Framework Programme of the European Union has just started. The general aims are (i) Promotion of resource-oriented sanitation concepts as a route to sustainable sanitation and to fulfil the UN MDGs; (ii) Implementation of resource-oriented sanitation concepts in four model cities in East Africa (Arbaminch, Ethiopia; Nakuru, Kenya; Arusha, Tanzania; and Kitgum, Uganda); (iii) Researching the gaps for the implementation of resource-oriented sanitation concepts in peri-urban areas; and (iv) Development of a generally applicable adaptable framework for the development of strategic sanitation & waste plans (SSWPs).

1.2 Problem Definition

Apparently a paradoxical situation is emerging with respect to urban services in less developed countries. On the one hand a huge demand for urban infrastructure has resulted from rapid urbanisation; on the other hand, existing infrastructure is decaying

[9] Not having access to improved sanitation means either being dependent on public or shared latrines, on a pit latrine without slab, on an open pit, on a hanging toilet, on a bucket latrine or simply having to defecate anywhere (WHO, UNICEF 2005).

[10] Source: http://www.un.org/ga/61/second/proposalslist.html

before completing its design life. Operation and maintenance (O&M) is the key to enhancing the sustainability of existing infrastructure and assets. However, there is a general lack of understanding by stakeholders about the role of operation, maintenance and sustainability in the context of good governance (Sohail et al. 2001).

Often the dimension of O&M is underestimated – planners tend to either only see the technical or financial side of it. However, O&M has impacts on many different levels and it is influenced by a variety of processes and factors. O&M has to be planned regarding its technical, financial, institutional, legal, socio-cultural and environmental context; otherwise any approach to O&M is likely to fail.

1.3 Objectives

In the context of sustainability, a project just providing facilities and neglecting O&M, is doomed to failure. O&M of sanitation systems have to be planned early in the project, to ensure sustainability in the whole project phase and afterwards. This thesis is dealing with O&M of resource-oriented sanitation systems[11]. It aims at giving a comprehensive overview over the framework conditions that are necessary for sustainable O&M. Some focus is made on management and financing issues. Research questions are:

- Literature study
  - What framework conditions are necessary for sustainable O&M?
  - What management and partnership options for O&M (and for sanitation systems in general) do exist/ are feasible for developing countries?
  - What financing strategies do exist and what are possible financial resources for cost recovery?
- Case study
  - What are the main problems/constraints for O&M of existing services in Nakuru, Kenya?
  - How suitable is the current composting scheme for an upgrade to co-composting[12]?

The thesis consists to the largest part of a literature survey with the aim to give guidance for the further development of operation and management strategies within the ROSA project. The case study will link some of the gathered information to the actual situation in one of the project towns.

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[11] A sanitation system is compromising the users of the system, the toilet infrastructure, the collection, transport, treatment, and management of end products (human excreta, solid waste, grey water, storm water and industrial wastewater) (IWA 2006).

[12] "The term co-composting refers to the composting of two or more raw materials together, in most cases a combination of human or animal waste with household garbage or other organic materials." (Lardinois, van Klundert 1993)

2 Approach and Methodology

2.1.1 Literature Survey

A lot of information on sanitation in developing countries is available on the Internet nowadays, not only from international development agencies but also from governmental and non-governmental organisations in developing countries. Generally most of this information is in English language and can be viewed or downloaded free of charge. A web-based literature survey was supposed to provide most of the needed information for the thesis. However, several books and journals which were not available online were obtained through libraries or by accessing online-journals through the university account. Furthermore a large set of electronic documents and a small but valuable stock of books and reports were available at the EcosanClub office in Vienna.

For the web-based survey four main search services were used:

- Search engines
- Portals, subject gateways and websites of specialised organisations
- Specialised water and sanitation databases
- Discussion lists

Search engines

Search engines generally provide the best results by using the 'best-match' method. This method involves typing as many search terms related to the topic. The search engines used for the survey were Google (http://www.google.com) and Metacrawler (http://www.metacrawler.com). Metacrawler is a meta search engine - that means that it searches via several other search engines and this way gets more results than single search engines. All search engines, however, have some limitations (Krukkert, Dietvorst 2004):

- Search engines only index the first part of a web page
- A search engine will often not be able to search the so called 'invisible web' or 'deep web'. This means that one will not find information:
  - stored in database records (libraries, yellow pages)
  - stored in pages that require login
  - stored in web pages not indexed by search engines, e.g. recent addition, or pages without links
  - hidden (deeply) in the site structure of a web site

Portals, subject gateways and websites of specialised organisations

A large number of gateways and portals on water and sanitation emerged in the past years. These portals are client-oriented web sites, which offer visitors a broad array of interactive resources such as news, data bases, discussion forums, search options, space to collaborate online and links on water/sanitation-related topics (Krukkert, Dietvorst 2004). Furthermore, many organisations active in the field of water and sanitation, offer their research results, project reports and other publications for download on their web-sites. Some of the very useful portals and websites are given below:

- *IRC International Water and Sanitation Centre*
  http://www.irc.nl
- *Sanitation Connection*
  http://www.sanicon.net/
- *Water, Engineering & Development Centre (WEDC)*
  http://info.lut.ac.uk/departments/cv/wedc/index.html
- *WatsanWeb*
  http://www.skat.ch/watsanweb/
- *Water and Sanitation Program (WSP)*
  http://www.wsp.org
- *World Bank Water Supply and Sanitation*
  http://www.worldbank.org/watsan
- *World Health Organization, Water, Sanitation and Health*
  http://www.who.int/water_sanitation_health/en/
- *BPD Water and Sanitation*
  http://www.bpdws.org/
- *EcosanRes*
  http://www.ecosanres.org/
- *Sandec*
  http://www.sandec.ch
- *WSSCC*
  http://www.wash-cc.org./
- *WASTE*
  http://www.waste.nl/
- *GTZ*
  http://www.gtz.de/ecosan

Specialised bibliographic water and sanitation databases

By using a search engine one might not be able to retrieve information stored in a database. Therefore it is good to check databases separately when searching for specific information. Some of the bibliographic databases are free:

- *IRCDOC, library database of the IRC International Water and Sanitation Centre*
  http://www.irc.nl/ircdoc
- *WELL Document Catalogue*
  http://www.lboro.ac.uk/well/Activities/document-catalogue.htm

Others are free to search and pay per view. These databases cover a large number of scientific online-journals:

- *Sciencedirect:*
  http://www.sciencedirect.com/science/search
- *Ingenta*
  http://www.ingentaconnect.com/search
- *Scirus*
  http://www.scirus.com/

Discussion lists

Discussion lists are useful to keep up to date in the field of interest, and to get expert answers on posted questions. Most lists also offer the possibility to search the list archives and certain topics have already been discussed before, so that there is often no need to post a question. Some basic questions were noted before, but the interview was structured quite flexible to adapt to emerging issues.

The EcosanRes discussion list (http://groups.yahoo.com/group/ecosanres) is a forum for people active in the field of Ecological Sanitation (Ecosan) and leading experts use this mailing list to exchange information. After subscribing, one can post messages and receive posted messages per email.

2.1.2 Case study

The information for the case study was gathered by using observation and semi-structured interviews. For the interviews it was decided to go for a loose form of the neutral interview, where the interviewer remains reserved but interested and avoids commenting (positively or negatively) on the informant’s attitude (Atteslander 1969). Some basic questions were noted before, but the interviews were structured quite flexible to adapt to emerging issues.

3 Resource-Oriented Sanitation

At first the term sanitation has to be defined:

According to Tayler and Parkinson (2000), ‘sanitation’ can be defined as a system for promoting sanitary health conditions. The use of the word ‘system’ suggests that sanitation is not preliminary about physical facilities but rather about the services that are provided through those facilities. Sanitation is sometimes viewed in terms of either excreta disposal or solid waste management. However, sanitary health conditions require a combination of these two with additional attention to storm water drainage. In this thesis the term ‘sanitation’ will mostly refer to human excreta rather than solid-waste or storm water management. This is due to the focus on human waste in the thesis, which also reflects the focus within the ROSA project.

As said before, the ROSA project will make use of methods that aim at conserving and recycling resources from human excreta, wastewater and solid waste. Ecosan, can be said to be such an approach and will be described now.

3.1 Background Information

Esrey et al. (2001) distinguish three different ways for managing human excreta at household level, as depicted in Figure 2.

- Drop-and-store:
  This option is based on the storage of human excreta in pits or septic tanks. This is the basic sanitation option in Sub-Saharan Africa.
- Flush-and-discharge:
  This option is water-based and dilutes the excreta and flushes it away. The device is a water toilet connected to a sewerage system. The system needs large amounts of water and is only appropriate if financial capacity is sufficient - due to the high cost in pipe networks and treatment plants.
- Sanitise-and-recycle:
  This approach is called Ecosan. It treats human excreta as a resource. Urine and faeces are stored and processed on-site and then, if necessary, further treated off-site until they are hygienically safe. Facilities from low-cost to high-end exist.

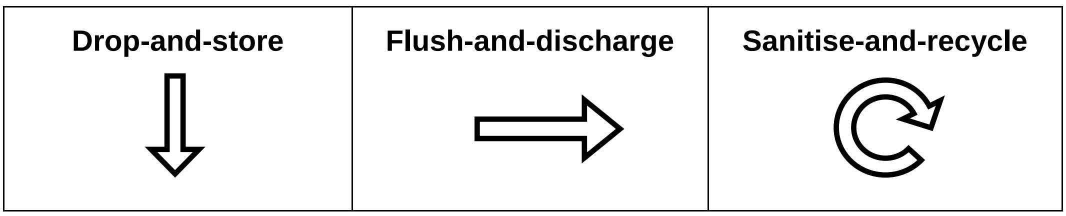

Figure 2: Three basic ways for managing human excreta (Müllegger 2002)

3.1.1 Drop-and-Store

Drop-and-store is the most common form of sanitation in Africa. Human excreta are collected in a vault or pit under the toilet and stored on-site. As sewer connection rate is very low, 70% - 90% of the households overall and basically all poor households deal with their own waste by building their own latrines or septic tanks or hiring others to do it. The options for drop-and-store disposal of human waste in African cities are depending on the physical conditions and on how much money they can spend on construction and periodic emptying. The solutions range from a simple pit to a water closet with provision for flushing with a soak pit for the waste water, or, at the high end of the market, a lined septic tank. Pit latrines of different kinds and bucket latrines are a common sanitation facility in many parts of African cities (Collignon, Vézina 2000).

Figure 3 shows the succession of sanitation options from the high income city centre to the low-income urban fringe, as it is typical for many African cities. Furthermore the sanitation market in regard to emptying possibilities is shown.

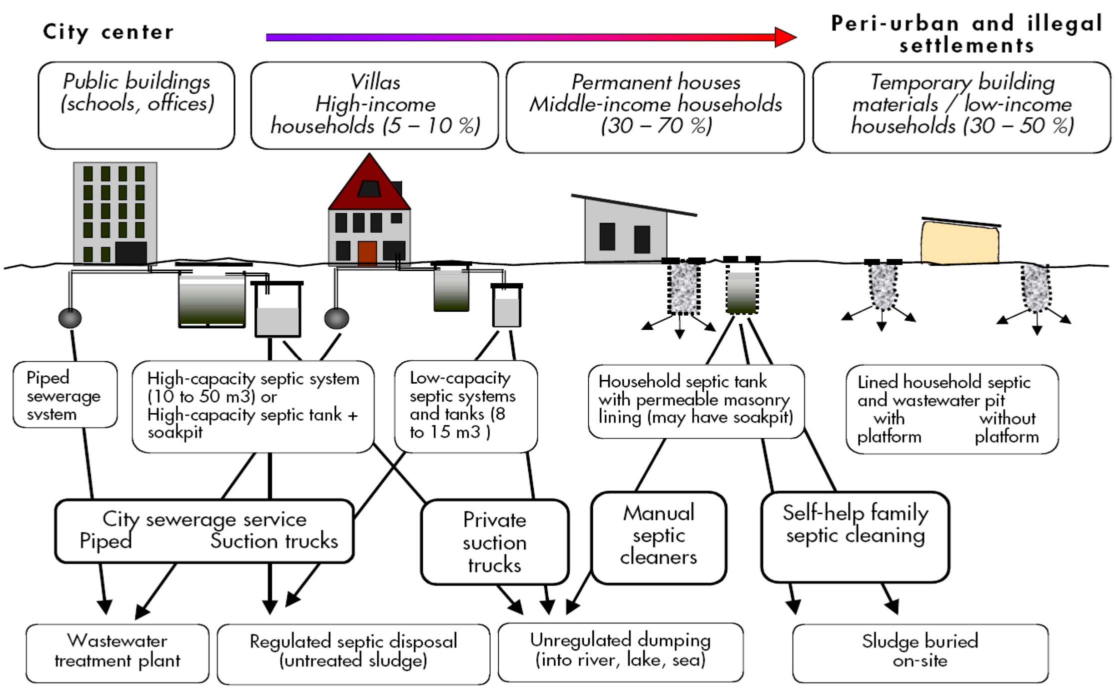

Figure 3: Overview of how the sanitation market works from downtown to urban fringe (Collignon, Vézina 2000)

After emptying of the drop-and-store facilities FS is buried on site or close to the vicinity in case of manual emptying. If suction trucks can be afforded the FS is transported and large amounts of FS are usually dumped indiscriminately into the environment due to lacking disposal facilities. Wastewater in many areas is directed to open stormwater drains and poses a threat to public health. Unsealed pits allowing fluids to drain can pollute water sources and groundwater. Nearby wells or water bodies may be polluted with pathogens and nitrogens. Environmental pollution is furthermore often caused by effluents of not regularly de-sludged septic tanks or community toilets (Collignon, Vézina 2000).

3.1.2 Flush-and-Discharge

This option is based on water-flush toilets with sewer connection and is sometimes referred to as the ‘conventional approach’ in Europe. Flush-and-discharge systems require large amounts of water for flushing – making the approach inappropriate for water-scarce regions. Different sources of wastewater, all having different characteristics (al requiring different methods of treatment) are conveyed in the sewer pipes and either discharged to water-bodies (Figure 4) or transported to treatment plants. From the household perspective it is the most convenient option, an out-of-sight out-of-mind solution, also called ‘flush-and-forget’. From a global perspective, vast amounts of wastewater are discharged into the environment without any treatment.[13] However, in some developed countries a more or less technically sophisticated system with centralised wastewater treatment plants exists.

The conventional approach has often been tried to copy by developing countries as it was perceived as the superior, or maybe as the most convenient solution. But, how for example Parkinson (2003) states, the provision of conventional sanitation systems has mostly failed for low-income areas. High financial and institutional capacity is a precondition for the functioning, as management is complex and investment and O&M are expensive.

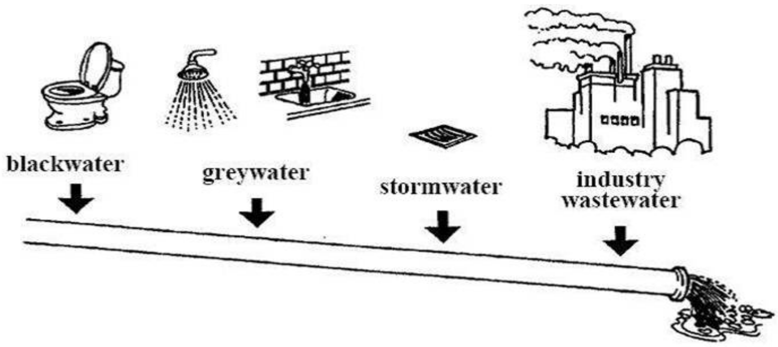

Figure 4: Conventional water-based sanitation (Heeb et al. 2006)

Werner et al. (2003) summarise the following shortcomings of the conventional approach:

- Unsatisfactory purification or uncontrolled discharge of more than 90 % of wastewater world-wide

[13] Even in the City of Brussels, at the heart of Europe where environmental legislation is made for the countries of the EU, construction of the city’s first wastewater treatment plant began only recently (IWA 2006).

- Pollution of water bodies by organics, nutrients, hazardous substances, pathogens, pharmaceutical residues, hormones, etc.
- Unacceptable health risks and spread of disease
- Severe environmental damage and eutrophication of the water cycle
- Consumption of precious water for transport of waste
- High investment, energy, operating and maintenance costs
- Frequent subsidisation of prosperous areas, and neglect of poor settlements
- Loss of valuable nutrients and trace elements contained in excrement through their discharge into water bodies
- Impoverishment of agricultural soils, increased dependence on the chemical fertilisers
- Predominance of combined central systems, resulting in problems with contaminated sewage sludge
- Linear end-of-pipe technology

3.1.3 Sanitise and Recycle

Ecosan is a new holistic paradigm in sanitation, based on the systematic closure of local material-flow cycles. It is introducing the concept of sustainability and integrated, eco-system oriented water and natural resources management to sanitation and water management (Werner et al. 2003). Figure 5 shows the principle of recycling nutrients and organic matter from human excreta to agriculture (via treatment), for plant uptake and soil conditioning. The produced crop is finally consumed by people and the loop is closed locally.

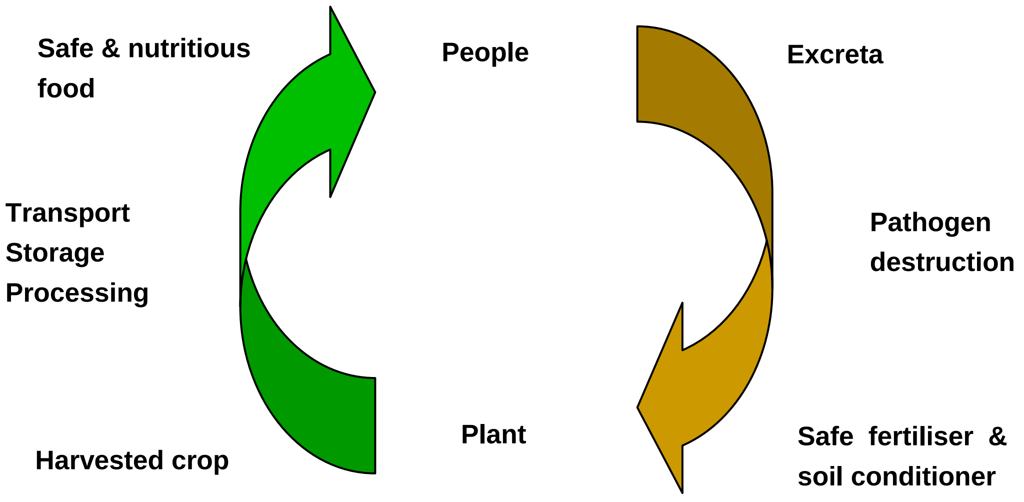

Figure 5: Closing the nutrient loop (Esrey et al. 2001)

The Ecosan approach is aimed at:

- saving water
- preventing pollution and disease
- returning the nutrients in human excreta to the soil.

The underlying goal is to close the nutrient and water cycles with as little expenditures on material and energy as possible. Human excreta are stored and processed on site and if necessary, further processed off site until they are free of disease organisms. The nutrients contained in the excreta are then recycled by using them in agriculture. In contrary to the conventional approach human excreta are seen as resources rather than waste (Winblad, Simpson-Hérbert 2004).

Most people can easily understand that water should not be wasted for flushing in areas where it is (or is becoming) scarce. The need to recycle nutrients is probably less commonly known. That an approach aimed at recycling nutrients is needed is documented by the following facts:

- Soil depletion is a huge problem in many countries although this is basically underestimated (UN 2006) - especially African soils are depleting in nutrients (Morgan, SEI 2004).
- Phosphorus (P) reserves are shrinking rapidly and prices are expected to rise in the near future (McCann 2005).
- More than one third of the global fertiliser consumption (which is approximately 135 million tons of fertiliser per year) could be covered by the reuse of wastewater (Panesar et al. 2006). Fertiliser industry is one of the biggest green-house gas producers and the production relies on non-renewable resources (Winblad, Simpson-Hérbert 2004)

Furthermore, over 50% of the absolute poor live in urban areas and spend much of their income on food. Basically their dietary intakes are nutrient limited. Yet the import of food is unaffordable to most of them. Lowering the costs of inputs, like artificial fertilisers, and producing food closer to where people live can reduce food production costs (WHO 2006).

“Unlike conventional sanitation systems, Ecosan systems not only control the direct hygienic risks to the population but also protect the natural environment. In making the organics, nutrients and trace elements available to agriculture, soil fertility is preserved and long-term food security is safeguarded.” (Werner et al. 2003)

3.2 Urine, Faeces, Greywater and Faecal Sludge [14]

In the Ecosan approach urine, faeces and greywater are seen as individual resources. This is reflected in some technologies commonly applied in this approach. These facilities collect the resources separately and make use of their different characteristics in nutrient content and treatment requirements.

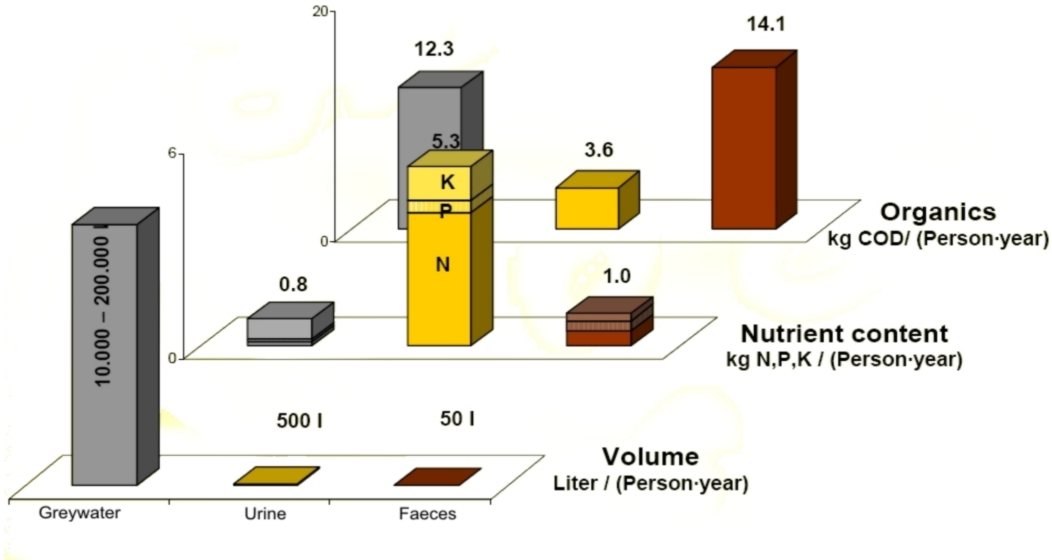

Figure 6: The composition of household wastewater[15] (Lange et al. 2000)

Figure 6 depicts the average composition of household wastewater. It is clearly shown that most nutrients are excreted with the urine, while organic matter is concentrated in faeces. Greywater contains only minor amounts of nutrients but has the largest quantity by far. Amount and composition of the wastewater fractions, especially of greywater may vary; hence the figures provided should be seen as giving relations.

As more than 75% of houses in large cities and up to 100 % of houses in towns in sub-Saharan Africa are served by drop-and-store sanitation facilities and these facilities produce thousand of tons of FS, which is very often indiscriminately dumped into the environment, faecal sludge management (FSM)[16] should be considered as an integral part of any Ecosan approach towards solving African cities sanitation problems. Ecosan aims to recycle human waste of which FS is an important part. The divergence between the two concepts is that FSM focuses on the collection and treatment proc-

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[14] Information for this chapter is taken from (WHO 2006) if not marked otherwise.

[15] Assuming the use of non phosphate-containing detergents

[16] According to Vodounhessi (2006): "Faecal sludge management is the management of sludge to avoid an unhealthy environment, such as that caused by indiscriminate dumping, overflow of septic tanks or community toilets, unhygienic use of the sludge in agriculture, etc. A proper FSM system includes adequate de-sludging of sanitation facilities, safe handling and transport of sludge, treatment of sludge, and safe disposal or reuse, but where reuse is not necessarily the main focus."

esses of a large amount of wet excreta, while Ecosan focuses on the human excreta generation process (e.g. on producing dry excreta separated from urine) and on the reuse process. (Vodounhessi, Münch 2006)

3.2.1 Faeces and Urine

Produced amount

The fibre content of the diet influences greatly the amount of faeces excreted. In Sweden it is estimated at 51 kg wet mass/person per year, in China measured at 115 kg/person per year and in Kenya measured at up to 190 kg/person and year. This equals a range of 0.14 – 0.52 kg/person and day.

The amount of urine produced is more constant and ranges between 500-600 l per person per year (respectively 1.4 – 1.7 l/person and day). (Jönsson et al. 2004)

Nutrients

The amount of nutrients in faeces and urine basically correspond to the amount of nutrients in the food consumed[17]. The following table shows estimated nutrient amounts in excreta, based on the dietary intake data of the specific countries:

Table 1: Estimated excretion of nutrients in kg per capita and year in different countries

Country		N [kg/cap, yr]	P [kg/cap, yr]	K [kg/cap, yr]
China	Urine	3.5	0.4	1.3
	Faeces	0.5	0.2	0.5
	Total	4.0	0.6	1.8
Haiti	Urine	1.9	0.2	0.9
	Faeces	0.3	0.1	0.3
	Total	2.1	0.3	1.2
India	Urine	2.3	0.3	1.1
	Faeces	0.3	0.1	0.4
	Total	2.7	0.4	1.5
South Africa	Urine	3.0	0.3	1.2
	Faeces	0.4	0.2	0.4
	Total	3.4	0.5	1.6
Uganda	Urine	2.2	0.1	1.0
	Faeces	0.3	0.3	0.4
	Total	2.5	0.4	1.4

Source: (Jönsson et al. 2004)

[17] For children the situation is slightly different: While the body is still growing, some nutrients are taken up and integrated into the body’s tissues. But these are only small amounts.

In contrast to human urine, excreted faeces contain only a small portion of plant nutrients, which reside in undigested fractions of food. The total excreted quantity of nutrients through faeces per year is about 0.4 kg of Nitrogen (N), 0.2 kg of P and 0.4 kg of potassium (K) (Table 1). However, these nutrients are not immediately plant available. The undigested food residuals have to be degraded before they become available. That means, that nutrients in faeces take more time to be plant available than the nutrients in urine.

From Table 1 follows that annually each person excretes about 3 kg of N, 0.3 kg of P and about 1 kg of K contained within urine. N is found in the form of urea, P as phosphate and K as ions. At the same time urine makes up to less than 1% of the total wastewater volume. The majority of the nutrients are easily available for plant-uptake, making urine a very good fertiliser. (Jönsson et al. 2004)

Pathogens

Concerning human health, faeces is by far the most critical fraction of wastewater. Faeces may contain pathogenic species of bacteria, viruses, parasitic protozoa and helminths. These organisms once excreted either may be:

- immediately infectious (i.e. bacteria and viruses),
- or may require a period of time outside of the body to become infectious, or
- may require an intermediate host before becoming infectious (i.e. bilharzia)

From a risk perspective, exposure to untreated faeces is always considered unsafe, due to the potential presence of high levels of pathogens, which reflects the level of pathogen presence in the user group. Die-off or survival of excreted pathogens is an important factor influencing transmission. In principle, most pathogens die off upon excretion. However, there are exceptions and safe storage and treatment of faeces is of significant importance. Furthermore hand washing and other simple behaviours can reduce the risk of infection dramatically.

Urine does normally not contain pathogens, some exceptions however exist.. The WHO (2006) concludes that "pathogens that may be transmitted through urine are merely sufficiently common to constitute a significant public health problem (…) *Schistosoma haematobium* is an exception in tropical areas, however, with a low risk of transmission due to its life cycle." The main risk arises from faecal cross contamination in the toilet, thus user care and a good technology for separating the flows are of significant importance.

Further substances that may be of concern

Heavy metal levels depend on the heavy metals present in the digested food. The content is usually low and of no concern. Generally spoken, faeces contain more metals than urine.

Urine may contain hormone active substances (among them, polychlorinated biphenyl) and chemicals used in industrial detergents, as plastic additives, in pesticides and antifoulings, body care products, and furthermore medical residues like antibiotics. It is supposed that the risk of a prevalence of these substances in food is low, as they are degraded by soil bacteria easily (Jönsson et al. 2004).

Reuse properties

Faeces:

Faecal matter is especially rich in phosphorous, K and organic matter. The organics and nutrients contained in it can be used as a dry fertiliser and soil conditioner. After processing, an earthlike inoffensive material is obtained which shows valuable soil improvement qualities (better structure and rise of the water retention and ion-buffering capacity) and a prolonged fertilising effect (Morgan, SEI 2004). Humus from the decomposition process also helps to maintain a healthy population of soil organisms that can protect plants from soil-borne diseases (Sawyer et al. 2003). If the faecal matter has been sanitised through the addition of alkaline material (e.g. ash) its high pH value can be beneficial for neutralising acidic soil conditions.

Urine:

Johansson et al. (2001) state that: "Human urine is a quick-acting fertiliser that can replace mineral fertiliser in cereal crop production. The relationship between N, P, K and sulphur is well-balanced and, with appropriate doses, broadly corresponds to the needs of cereal crops."

Numerous composting techniques exist which may profit of water and nutrients contained in urine. Compost wetted with urine reaches higher composting temperatures and has a higher nutrient value although reasonable amounts of ammonia might evaporate (Pinsem et al. 2002). Biodegradable waste degrades more quickly when urine is added[18] and furthermore the obtained N-P-K values are higher with urine addition. However, the different treatments have a comparable percentage of total organic matter and pH values in their respective compost products (Ngilangil 2005).

Morgan (2004) experienced that when urine was used on deficient soils, there is not enough P and K available, which can reduce fruiting, particularly in those plants (e.g. tomato, onion and potato) which are known to require quite high levels of K. It happens that the achieved yield of crops fertilised with urine varies depending on the soil conditions. As with chemical fertilisers, the effect is lower on soil poor in organic content. "Under these conditions, soil fertility may benefit from using both urine and faeces or other organic fertilisers alternatively applied in consecutive years and for different crops" (WHO 2006).

Figure 7 demonstrates the fertilising value of urine and compost made of faecal matter. Left photo: The maize plant on the right is being fed with a 3:1 mix of water and urine (0.5 litres) three times per week. The maize on the left is irrigated with water only. Right photo: The photo shows onion grown on poor soil (left) compared to onion grown on the same poor soil mixed with an equal volume of faecal compost after 4 months of growth (right) (Morgan, SEI 2004).

Figure 7: Yield improvement through urine (left) and compost (right) (Morgan, SEI 2004)

3.2.2 Greywater

The main sources of greywater are laundry, bathroom and kitchen. Greywater volume and composition may vary enormously with:

- sanitary standards
- awareness of the need for water conservation
- water availability and raw-water composition
- lifestyle
- family size
- age of residents
- eating habits
- detergents

Produced amount

In low-income areas where water often is hand-carried from taps, greywater volumes produced may be as low as 20-30 litres per person per day. When more water is available, the production of greywater increases, but it seldom exceeds 100 litres per person per day in developing countries. In industrialised countries, greywater production is normally in the range of 100-200 litres per person per day.

[18] Biodegradable waste decomposed in 48-50 days without addition of urine while urine application speeds up the decomposition process to 42-43 days (Ngilangil 2005).

Nutrients and chemical parameters

Greywater contributes 10-60% of the total P in a mixed wastewater system depending on the detergents used. Average phosphorous concentrations are typically found within a range of 4–14 mg/l in regions where non-phosphorous detergents are used. However, they can be as high as 45–280 mg/l in households where phosphorous detergents are utilised (Morel, Diener 2006). Furthermore about 10% of the N in wastewater is coming from greywater. N concentration in greywater is often 10 mg/l or less. Greywater contains 50% or more of the readily degradable organic matter in household sewage, but the concentrations are highly variable depending on household practices. Table 2 shows typical characteristics of greywater as a function of greywater production.

Table 2: Low, typical (bold) and high BOD, TSS, TP, and TN concentrations as a function of greywater production; typical daily loads in greywater

Daily greywater production	≈ 200 l	≈ 100 l	≈ 30–50 l	Loads
BOD_5 [mg/l]	50...**150**...600	100….**250**...500	300...**700**...1500	20–50 g/p/d
TSS [mg/l]	50...**100**...500	50.....**150**...500	150...**500**...1500	10–30 g/p/d
TP [a] [mg/l]	1...**10**...50	1.....**15**...100	5.....**30**...200	0.2–6.0 g/p/d
TN [mg/l]	1...**5**...30	1...**10**...50	1...**20**...80	0.8–3.1 g/p/d

[a] The level of phosphorous in greywater strongly depends on the presence or absence of phosphorous in laundry and dishwasher detergents. High values must be expected where phosphorous-based products are used in the household.

Source: (Morel, Diener 2006)

Pathogens

As with urine, the main hazards of greywater originate from faecal cross-contamination. However, greywater may contain a high load of easily degradable organic compounds, which favours the growth of faecal indicators. Hence, bacterial indicator numbers may lead to an overestimation of faecal loads and the associated risk.

Further substances that may be of concern

The heavy metal content in greywater may be higher than in faeces and urine but is normally lower than in chemical fertilisers, for example. It is usually of no concern. The grease content varies widely; if large volumes of oil are used in the kitchen grease traps should be installed before further treatment. The amount of surfactants present in greywater is strongly dependent on type and amount of detergent used. It is ranging between 1 and 60 mg/l, and averaging 17–40 mg/l. In most Western countries non-biodegradable surfactants have been banned in the 1960s, but these environmentally problematic organic chemicals are still used in many developing countries. There are many conflicting literature studies on the fate and impact of surfactants in the natural environment (Morel, Diener 2006). Furthermore greywater can contain many other household chemicals and pharmaceutical residues. Salinity of greywater is normally not problematic, but can become a hazard when greywater is reused for irrigation.

Reuse properties

After treatment greywater can be used for irrigation of agricultural crops in water-scarce regions, but it can also be used for groundwater recharge or industrial or urban reuse or discharged into surrounding watercourse. Which option is chosen depends on the local situation. Although greywater should be regarded as a resource to be reused in agriculture, this option may not always be the most suitable. For example reuse might not be the best option in peri-urban areas where agricultural land may not always be available, and thus discharge to surface water can be more appropriate. "Disposal of treated greywater, be it through groundwater recharge or discharge into surface water, can be viewed as a very indirect and long-term reuse option as it re-enters the hydrological cycle" (Morel, Diener 2006). Collected grease and oil can be processed to biodiesel or may be added to biodigesters to increase gas yield.

3.2.3 Faecal Sludge

FS is sludge removed from all kind of on-site sanitation facilities such as septic tanks, bucket latrines, pit latrines, biodigesters etc. (Klingel et al. 2002). In contrast to sludge from wastewater treatment plants and in contrary to municipal wastewater, characteristics of FS differ widely by locality. Storage duration, temperature, intrusion of groundwater in septic tanks, performance of septic tanks, and tank emptying technology and pattern are parameters which influence the sludge quality and are therefore responsible for its high variability (Strauss, Montangero 2002). A basic distinction can usually be made between fresh, biochemically unstable ('high-strength') and biochemically fairly stable ('low-strength') sludge. Unstable sludge contains a relative large percentage of recently deposited excreta. Stable sludges are those, which have been retained in pits or septic tanks for months or years and which have undergone a certain biochemical degradation (Strauss et al. 2003). One example is septage, which is sludge from septic tanks and comprises usually settled and floating solids as well as the liquid portion. In contrast to fairly stable sludges, fresh undigested and biochemically unstable sludges exhibit poor solids-liquid separability (Strauss, Montangero 2002).

Nutrients and chemical parameters

Table 3 shows typical FS characteristics. It is based on results of FS studies in Argentina, Accra/Ghana, Manila/Philippines and Bangkok/Thailand. The characteristics of typical municipal wastewater as may be encountered in tropical countries are also included for comparative purposes (Strauss, Montangero 2002).

Table 3: Faecal sludges from on-site sanitation facilities in tropical countries

Item	Type "A" (high-strength)	Type "B" (low-strength)	Wastewater (for comparison purposes)
Example	Public toilet or bucket latrine sludge	Septage	Tropical sewage
Characterisation	Highly concentrated, mostly fresh FS; stored for days or weeks only	FS low concentration; usually stored for several years; more stabilised than Type "A"	
COD [mg/l]	20, - 50,000	<15,000	500 - 2,500
COD/BOD	5 : 1 .... 10 : 1		
NH_4-N [mg/l]	2, - 5,000	<1,000	30 - 70
TS [mg/l]	≥ 3.5 %	< 3 %	< 1 %

Adapted from: (Strauss, Montangero 2002)

Pathogens

The faecal material collected from latrine or toilet pits may contain high numbers of pathogens if it has been stored only for short periods of time (no more than l-2 weeks) prior to collection. Basically the same pathogens and therefore the same risks as with fresh excreta have to be considered (see chapter 3.2.1: Faeces and Urine) and subsequently health protection measures have to be taken. Secondary treatment serves to inactivate the pathogen levels.

Further substances that may be of concern

Heavy metals, hormone active substances, antibiotics, grease, surfactants and other household chemicals are potentially contained in FS. As FS is a mixture of the flows of urine, faeces and sometimes greywater, its composition depends on the composition of these flows.

Reuse properties

Often the sludge from on-site sanitation is used in an unhygienic way in agriculture because no sludge treatment is available (Klingel et al. 2002). On the one hand these methods expose people to health risks; on the other hand, wastewater reuse provides many with valuable food. The target would be an 'excreta-reuse-culture' which is based on sound treatment.

Treated FS has similar properties to processed faeces. The solids fraction of FS constitutes a valuable soil conditioner and fertiliser when stabilised and treated to the required hygienic quality. The nutrient value in the treated sludge will normally be higher than in treated faeces due to the contained urine. The undiluted liquid fraction from the treatment process will typically not be usable in agriculture because of excessive salinity.

3.3 Disease and Sanitation

3.3.1 Sanitation Related Diseases

Most diseases relating to poor sanitation are faecal-oral transmitted. That means that the excreted pathogens have to be ingested to cause an infection. Some sanitation related diseases can be transmitted other than by the faecal-oral pathway, for example schistosomiasis needs to develop in a freshwater snail before it can infect people. The pathogen infects people by penetrating skin which is in contact with infected surface water. Some bacteria (Salmonellae, Shigellae and Campylobacter, e.g.), have the potential to multiply outside the host primarily on food and at warm temperature. In many areas of Africa, Asia and Latin America, helminth, notably nematode infections (*Ascaris, Trichuris, Ancylostoma, Strongyloides,* etc.) are highly prevalent. *Ascaris* eggs are particularly persistent in the environment. Most helminth eggs contained in faecal or in wastewater treatment plant sludges end up in the biosolids generated during treatment. Infection with intestinal helminths poses the major human health risk associated with the agricultural use of untreated urban wastewater (Ensink, van der Hoek 2007). Hence, in many places, nematode eggs are the indicators-of-choice to determine hygienic quality and safety where biosolids are to be used as a soil conditioner and fertiliser (Strauss, Montangero 2002).

3.3.2 Cutting Transmission Pathways

Most pathogens can be transmitted either by direct contact to faeces (fingers), by contaminated water (fluids) or by contaminated food. Furthermore, flies or other insects can act as carriers of pathogens and transmit diseases either directly or by contaminating food (Winblad, Simpson-Hérbert 2004). In Figure 8 the pathways of faecal-oral transmission (arrows) and barriers to block these pathways (bars) are shown.

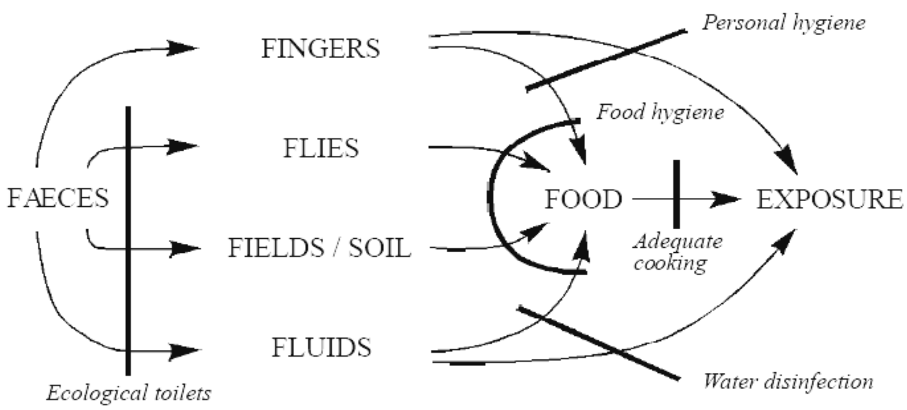

Figure 8: Transmission pathways - The F-Diagramm

Once excreted, pathogens will usually die off over time. As a general rule, pathogens survive longer when they are in lower temperatures, in a moist environment, and protected from direct sunlight. Furthermore, generally spoken helminths and viruses will survive longer then bacteria and protozoa (WHO 2006).

In the Ecosan approach, to reduce the risk of transmission, three main barriers against the spread of pathogens are used on the household level (Heeb et al. 2006):

Toilets

- Toilets contain excreta safely and prevent leachate to get in contact with water sources
- Toilets should prevent flies from getting in contact with faeces. Faeces are stored safely away from flies
- Sanitisation of excreta in the toilet (only sanitised products are put on the fields)

Personal hygiene

- The implementation of Ecosan projects should always go along with hygiene promotion and education. Washing hands, for example, could reduce the risk of diarrhoeal diseases by 42 to 47% (NWP 2006).

Food hygiene

- use of sanitised fertiliser only
- no contact with contaminated water
- hygienic behaviour (washing hands before cooking & eating)
- adequate cooking should be promoted

3.3.3 Containment and Treatment of Excreta in Ecosan on-Site Facilities

The safe containment of excreta is crucial for health. Building a barrier against the spread of diseases caused by pathogens in human excreta should be the most important criterion for sanitation. A common practice in Ecosan projects is to separate the flows. The separate treatment of faeces, urine and grey water minimises the consumption of water. Another important advantage of this practice is that the flows can be treated according to the specific reuse requirements as the different fractions have different characteristics. The separation is, however, not a prerequisite in Ecosan, and Ecosan is also possible in combined flow systems.

Human faeces rather than urine and greywater contain most organisms that could cause diseases. The treatment of faeces will, if done properly, render it a safe product. A number of environmental factors are known to kill off faecal disease organisms. These are increases in storage time, temperature, dryness, pH, ultraviolet radiation, and competing natural soil organisms. In Ecosan facilities, usually excreta are stored in a processing chamber or a shallow pit for a while without addition of fresh excreta, until pathogen reduction renders the product safe for reuse. Primary treatment is taking place in the storage chamber through dehydration, decomposition and or alkaline treatment (Winblad, Simpson-Hérbert 2004):

Dehydration

- Lowering of moisture content to less than 25% through evaporation and addition of dessicant (sawdust, ash etc.)
- Pathogenic organisms are killed through deprivation of moisture
- Reduction in faeces volume but minimal decomposition of organic material

Decomposition

- Complex biological process in which organic substances are mineralised and turned into humus
- The speed of decomposition is influenced by:
  - amount of oxygen
  - temperature
  - moisture
  - pH value
  - ratio of carbon to nitrogen (C:N ratio)
  - competition among micro-organisms for nutrients
  - toxic by-products of decomposing organisms

Alkaline treatment

- Usually in conjunction with dehydration
- Rise of pH level to over 9 through addition of lime, ash or other alkaline substances
- Pathogen die-off through unfavourable pH conditions

As many factors influence the speed of sanitisation a guideline has to be adopted to assure the correct treatment method and time. Table 4 gives recommendations for storage and treatment of faeces and FS in on-site sanitation facilities:

Table 4: Recommendation for storage treatment of dry excreta and faecal sludge before use at the household and municipal levels[a]

Treatment	Criteria	Comment
Storage; ambient temperature 2-20 °C	1.5-2 years	Will eliminate bacterial pathogens; regrowth of E.coli and Salmonella may be considered if rewetted; will reduce viruses and parasitic protozoa below risk levels. Some soil-borne ova may persist in low numbers.
Storage; ambient temperature 20-35°C	>1 year	Substantial to total inactivation of viruses, bacteria and protozoa; inactivation of schistosome eggs (< 1 month); inactivation of nematode (roundworm) eggs, e .g. hookworm (Ancylostoma/Necator) and whipworm (Trichuris); survival of a certain percentage (1-30%) of Ascaris eggs(≥4 months), while a more or less complete inactivation of Ascaris eggs will occur within 1 year
Alkaline treatment	pH >9 during >6 months	If temperature >35 °C and moisture <25%, lower pH and/or wetter material will prolong the time for absolute elimination.

[a] No addition of new material

Source: (WHO 2006)

According to the WHO (2006), the reuse of treated human faeces in agriculture after primary on-site treatment should be encouraged if the following criteria can be met:

- Excreta storage without fresh additions > 1.5 years;
- Materials directly worked into the soil; Pathogen die-off (Withholding time one month);
- Produce washing with water / disinfection;
- Produce peeled or cooked.

<u>**WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater**</u>

To ensure sufficient pathogen die-off in a sanitation system, the system has to be designed and operated according to state-of-the-art scientific recommendations. The recommendations for treatment given in this thesis are taken from the *WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater* (2006), if not marked in another way. These guidelines are internationally authoritative although some countries maintain guidelines with a different approach. The WHO guidelines are the result of a scientific consensus of the best available evidence (Ensink, van der Hoek 2007). They are based on a tolerable burden of diseases, rather than faecal coliform guidelines, and on a quantitative microbiological risk assessment approach. The risk of disease from exposure to a specific pathogen is estimated and based on that the reduction in faecal coliform concentrations that need to be achieved to guarantee safe use of wastewater, excreta and greywater in agriculture is calculated. The guidelines furthermore take natural die-off of pathogens on produce into consideration and provide a multiple barrier risk reduction approach. A wider range of reduction measures such as irrigation techniques, and food preparation measures like washing or peeling of produce are considered, although the guidelines state that all these measures are complementary and should not be seen as alternative to wastewater (excreta, greywater) treatment (Ensink, van der Hoek 2007).

Key Issues

Current sanitation approaches have several shortcomings, especially in developing countries. Ecosan as an alternative approach aims at saving water, preventing pollution and disease and returning the nutrients in human excreta to the soil. In this approach human waste-flows are regarded as separate substances, each of them having its own properties and impacts on the environment and human health. Urine, faeces, FS and greywater differ, among other things, in their nutrient content and treatment requirements – a separation of the flows allows for individual treatment of each substance and facilitates sanitisation and reuse. Urine contains most of the nutrients and can be seen as a fertiliser for plants. Urine and greywater have been identified as having a rather low pathogenic risk - faeces and FS are potentially dangerous due to a high pathogenic risk. Transmission pathways from faeces/ FS to humans can be blocked by several barriers in the Ecosan approach. For ensuring sufficient pathogen die-off during treatment, the WHO guidelines (2006) are recommended as a manual. All this information is important to understand the basic requirements the operation of resource-oriented sanitation systems has to meet and should furthermore serve as a basis for the following chapter on resource-oriented sanitation systems.

3.4 Resource-Oriented Sanitation Systems

Where space is limited reuse can hardly happen on-site. Thus, a collection system on the communal or municipal scale is necessary for recyclates[19] of Ecosan facilities and for FS from drop-and-store sanitation options (as well as for greywater). The recycling of resources on the communal, municipal or urban level is usually done in five steps, which is depicted in Figure 9. Part A is the household facility, Part B represents the step of collection & transport, Part C is the step of treatment and storage, Part D is the transport to the reuse-site and E is the step of actual reuse or final deposition (if nobody wants to reuse). If the recycled products are used in agriculture, produced goods will be consumed by people and the resource loop is 'closed' locally.

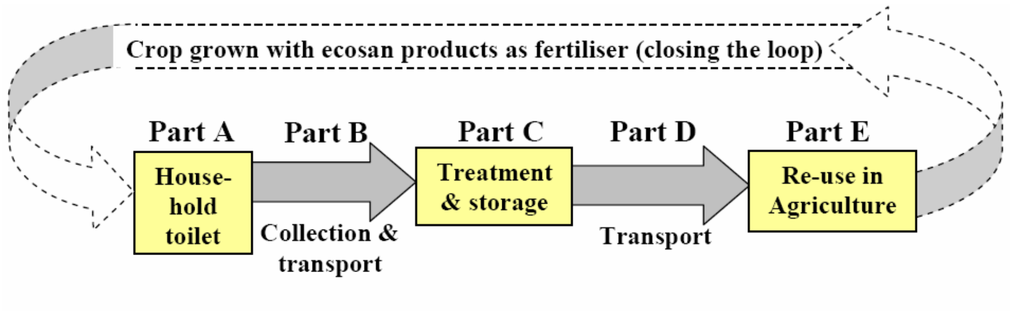

Figure 9: The 'Ecosan-loop' (Münch et al. 2006)

Of primary importance to the operators of the system are mainly steps A, B and C as the most important sanitation-aim, elimination of pathogenic risk, is reached by then. Furthermore, it is supposed that D (Transport) to and E (Reuse in Agriculture) are the responsibilities of customers[20], who are supposed to buy the produced fertilisers/ soil conditioners.

3.5 Part A: Household Facility

In the following chapters some toilet-technologies for on-site collection of human excreta are presented. Conventional on-site sanitation options, as well as Ecosan facilities are included. Ecosan facilities are stream separating systems, which means that greywater and human excreta are treated separately. They can be a cheap and sustainable option in many cases but they all require a high amount of user care in O&M. In Appendix C O&M tasks and responsibilities are shown for each of the presented facilities. However, no information on O&M of the Biosan latrine could be found in lit-

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[19] The term 'recyclates' refers to the processed waste-flows which can be seen as recycled goods, ready for reuse.

[20] However, if customers are not willing or able to buy the recyclates at the treatment stations, transport to a sales point or directly to the customer may become an important aspect. In the case that no demand for the recyclates is given, transport and deposition of the recyclates has to be organised by the system operator(s).

erature. Even after contacting the authors of a study on this facility, nobody was able to provide any information on O&M.

Depending on ownership and the number of users, three different types of toilet-facilities can be distinguished (Schaub-Jones et al. 2006):

- **Communal facility** Communal facilities are public toilets (which may be privately run). They are frequently found in busy public areas such as bus stops or markets, but also in poorer neighbourhoods or slums.
- **Shared facility** A shared facility is typically a latrine shared between multiple households (and often provided by a landlord). A shared key may prevent outsiders from using it, with maintenance (i.e. cleaning and the cost of emptying) shared between the users.
- **Household facility** With its greater convenience and privacy, this facility is most in demand, but also costs the most. Emptying can be a challenge; often mechanical pit emptiers cannot reach the household or are too expensive, so informal manual emptying (or unhygienic 'flushing' into the surrounding neighbourhood) is more likely. Household toilets, with their lower loading, can take longer to fill than the other facilities, and therefore are less likely to be considered regular 'customers' of whoever undertakes the emptying.

3.5.1 Wet Sanitation: Septic Tank or Aqua Privy Connected to a Soakaway

A common sanitation option in African cities is a (low) flush toilet connected to a septic tank (Figure 10). This system may work with a water seal to prevent insect nuisance and odour problems. The amount of water needed to flush depends on the water seal depth which is usually smaller (about 20 mm) than that of full-flush toilets (about 50 mm) used in conventional flush-and-discharge systems.

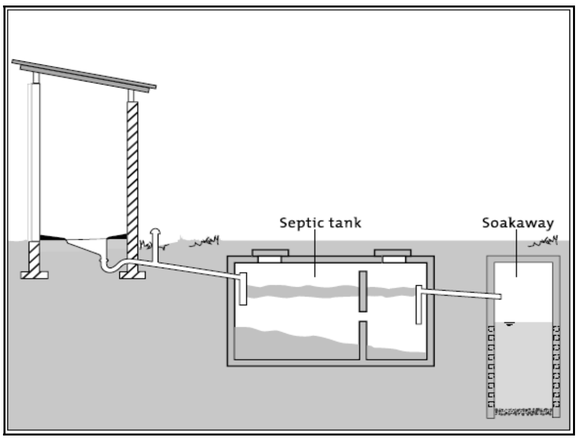

Figure 10: Toilet with septic tank (Brikké, Bredero 2003)

The septic tank is the most common unit for on-site pre-treatment of combined wastewater (greywater and excreta) and greywater (WHO 2006). Septic tanks have a water-tight settling tank with one or two compartments. Excreta are flushed into the tank by water (usually 2-5 litres) from a pipe that is connected to the toilet. If the septic tank is under the latrine, the excreta drop directly into the tank through a pipe submerged in the liquid layer[21]. If the tank is away from the latrine, the toilet usually has a U-trap. Some of the solids float on the surface as scum, while others sink to the bottom where they are broken down by bacteria to form sludge (also termed septage). The liquid effluent flowing out of the tank is hazardous to health and should be disposed of, normally by soaking it into the ground through a soakaway. Soakaways are pits designed to collect the liquid effluent of a septic tank and to allow it to soak into the soil. Every tank must have a ventilation system to allow methane and other gases to escape, since anaerobic digestion occurs. Septic tanks are more expensive than most other on-site sanitation solutions and require higher amounts of water. The accumulated sludge in the tank must be removed regularly, usually once every 1–5 years, depending on the size of the tank, number of users, and kind of use. The tank should be emptied when solids occupy between one-half and two-thirds of the total depth between the water level and the bottom of the tank.

The capacity of the soakaway should be at least equal to that of the septic tank. The soak pit may be filled with stones, broken bricks, etc., in which case no lining is needed, or it may be lined with open-jointed masonry. The top of the pit should be lined solidly, to provide firm support for the reinforced concrete cover. The cover is sometimes buried by 0.2–0.3 m of soil to keep insects out of the pit. The size of the soakaway is determined mainly by the volume of liquid effluents produced, and by local soil conditions. With large effluent flows, drainage fields may be more economical than soakaways. Planting trees adjacent to, or over, a soakaway can improve both transpiration and permeability (Brikké, Bredero 2003). Septic tanks can also be used as an intermediary settling facility for wastewater in conjunction with small-bored sewerage (see chapter 3.6.1: Wastewater Collection and Transport)

Disadvantages of the system:

- liquid effluent disposal is often managed inadequately and health problems arise
- pathogen destruction level is poor
- system is not suitable for areas where water is scarce, where there are insufficient financial resources to construct the system, or where safe tank emptying cannot be carried out or afforded
- if there is not enough space for soakaways or drainage fields, small-bore sewers have to be installed (Brikké, Bredero 2003)
- minimum distance to water sources (if effluent is drained) 15-30m (Rottier, Ince 2003)

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[21] This design is also called ‘aquaprivy’. Aquaprivys are normally smaller and cheaper than conventional septic tanks and less water is used to flush.

- risk of groundwater contamination (Rottier, Ince 2003)

Interface between toilet and collection service

The septic tank should be easily accessible for vacuum trucks to facilitate emptying.

3.5.2 Dry Sanitation: Pit-Latrines

The most common facilities in peri-urban of areas of Africa are probably pit-latrines. They can be described as anaerobic accumulation systems for stabilising human wastes (Chaggu 2004). Pit latrines, often used in both in rural and urban settlements of developing countries, vary in design. Improved versions of the traditional pit latrine include a ventilation pipe and/or a cover plate for the squat-hole (Ventilated improved pit latrine (VIP), see Figure 11).

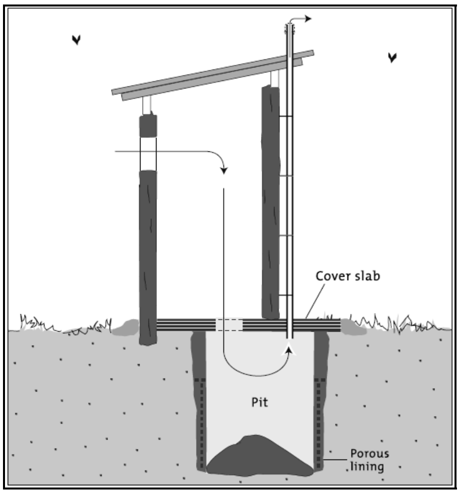

Figure 11: Ventilated improved pit-latrine (Brikké, Bredero 2003)

The superstructure may be a simple shelter or a brick construction with or without a vent pipe and with or without a seat. Space and ground conditions and cultural preferences affect the choice of technology (MIT 22.10.2003). The pit can be lined, which means stabilised with bricks and concrete, or unlined. Excreta are deposited into the pit when the toilet is used. The fluid parts are allowed to soak through the porous lining of the pit and the solid matter is accumulated. Pit-latrines can also be designed as twin pit-latrines with alternating use of the pits. When one pit is full the other pit, being left for decomposition for about 1 year, can be excavated and used again.

The advantage of a VIP in comparison to a simple pit-latrine is the vent-pipe, which ideally prevents flies from breeding in the pit and decreases odour problems. Insects inside the pit fly towards the light when leaving. As the superstructure is ideally built so that it is dark inside, the flies will try to leave through the vent-pipe which is fitted with a fly trap. Flies are a big problem because they transmit diseases. Wind blowing across the top of the vent-pipe creates a slight below atmospheric pressure and air is drawn into the squat hole and up the vent-pipe (Figure 11). This way odour is transported outside without bothering the toilet user.

Under favourable circumstances the VIP can be an appropriate technology, because the system is simple, no water is required for flushing and it is low-cost. Favourable conditions are:

- Low groundwater table
- No risk of flooding
- Deep, stable and permeable soil
- Emptying and maintenance are carried out reliably
- Good quality of pit, slab and superstructure

In areas with a high groundwater table or areas prone to flooding there is a risk of groundwater contamination through pathogens and/or nitrate. A minimum distance of 2 m between pit base and groundwater level should be applied. The minimum distance to water sources should be 15-30 meters. For crowded areas pit-latrines are often unsuitable as they almost always have negative influence on the groundwater quality (Cave, Kolsky 1999).

Interface between toilet and collection service

The pit should be easily accessible for vacuum trucks to facilitate emptying. However, unlined pits are normally not emptied by mechanical means.

3.5.3 Dry Sanitation: Composting Toilets

A variety of composting toilet models exists. Some are entirely built above ground on a raised chamber; this makes access easier, but is also more expensive to build. Other models have a shallow pit dug into the earth and a simple superstructure built above. For humid climates models exist which drain the fluids and treat them separately in a wastewater garden (Rose 1999).

Composting toilets rely mainly on aerobic degradation of organic matter resulting in a volume reduction of the excreta of 70-90% if properly designed. The C:N ratio of excreta including urine is 7-8, but for well functioning composting it needs to be raised to between 30 and 35. This can be done by adding bulking material such as paper, wood or bark chips, sawdust, ash or other similar substances. The bulking material also serves to cover the fresh faeces and to obtain a better oxygen supply in the heap. If this is neglected the toilet will be a collection chamber for wet excreta with potential odour and fly breeding problems (WHO 2006). The toilet content should have a moisture content of only 50-60% (Sawyer et al. 2003). Proper ventilation will help improve odour control. Organic household waste can also be added to a composting toilet; either through an extra opening into the vault (A in Figure 12) or simply through the drop hole itself. All composting toilets have a collection chamber/ pit or a moveable container where faeces and urine are confined. They can be operated in a batch mode or continuously (Figure 12). Preferably they should be operated in a batch mode, because this eliminates mixing of fresh and matured material and is thus safer for persons emptying the toilet. An example for a batch mode operated toilet is the double vault system (B in Figure 12) where one vault is used while the other matures. The assumption is that after a certain period of time (usually 6-12 months) the excreta in the unused compartment are safe to handle and can be removed. Examples of composting toilet systems:

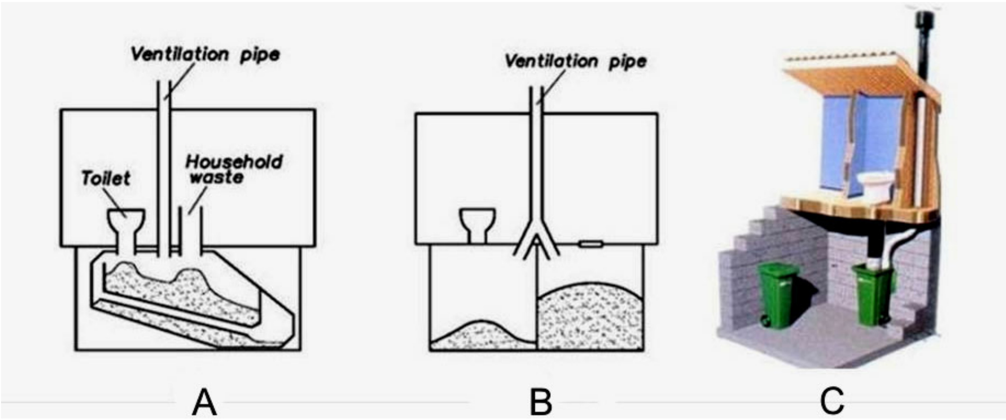

Figure 12: A) Continuous system; B) Batch system - double vault; C) Batch system with removable compartments (Heeb et al. 2006)

Triple vault systems also exist and provide even more assurance of pathogen kill because the duration of microbiological activity is lengthened in comparison to double and single vault options (Rose 1999).

Disadvantages:

Due to its complexity the composting process may prove difficult to manage within the chamber and thermophilic composting will usually not take place. The normal operating temperature range is mesophilic or ambient (WHO 2006). Pathogen reduction may require long maturation times or a secondary composting or storage period (see also Appendix B: Flowchart for the safe reuse of faeces). "Unless good operation can be ensured composting is not considered as a good choice for primary treatment but rather as an option for secondary treatment of faeces at a municipal level" (Schönning, Stenström 2004), where composting can be monitored. Rose (1999) furthermore suggests that double-vault composting toilets "are not generally feasible in densely populated urban areas unless the system is sealed to protect local groundwater resources." Experience shows that users generally are more satisfied with toilets with urine separation. The main complaints on the mixed composting system concerned insects, non-functioning or too wet compost, un-clean toilet and collection chamber being over-filled (Jönsson, Vinnerås 2007).

Interface between toilet and collection service

Versions with a moveable container (C in Figure 12) may be more convenient for projects with household collection than fixed vaults or processing chambers. Accessibility and size of the containers are a critical point. The smaller the containers are the more often they will have to be emptied, but the easier it is to lift them. Easy access is important for user satisfaction if toilets are operated by the householders themselves. For the collecting service, if existing, access should be designed that way that the chambers can be emptied from the street side.

3.5.4 Dry Sanitation: Dehydrating Toilets

A dehydration toilet is entirely built above ground. In contrary to the composting toilet the dehydration toilet aims at drying out excreta instead of optimising the conditions for composting. For efficient operation, neither water[22] nor urine should be added to the dehydration chamber. Non urine-separating models exist (Chiarawatchai et al. 2005) but they will not be discussed here as they are not commonly used. With the aid of solar heat, natural evaporation, ventilation and the addition of absorbent materials, the moisture content of faeces is reduced. This enhances pathogen destruction. Pathogen destruction is further enhanced by addition of alkaline material, such as lime or ashes. Similar to the VIP, the ventilation, which draws air through the toilet and out through the vent pipe helps to reduce odours. The absence of liquid and urine furthermore helps to minimise smell.

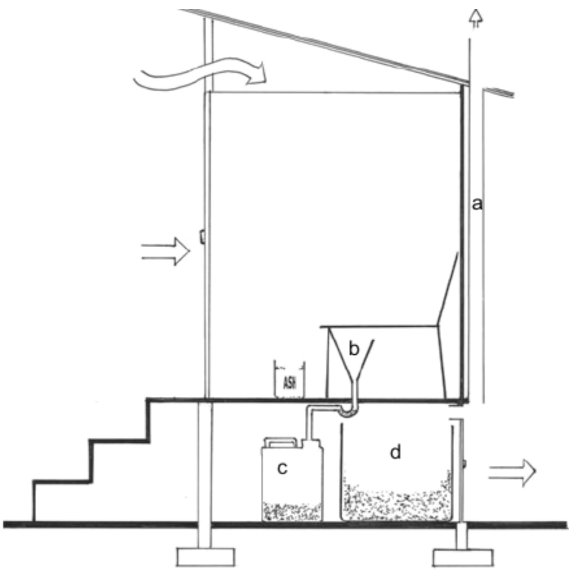

Figure 13: Single-vault dehydrating toilet with superstructure (NWP 2006)

[22] For people using water for anal-cleansing toilets with a sloped chamber bottom, topped with gravel can be built, in order to drain the excess liquid (Werner et al. 2005).

Figure 13 shows the sketch of a single-vault dehydration toilet with superstructure including a vent pipe (a). The airflow is marked with arrows. For designing the superstructure locally available materials of any sort are used. This model collects urine by using a funnel (b) in the front of a toilet seat, a cheap method if ready-made diversion slaps or seats are not available. Urine flows through a plastic pipe into the collection container (c). Faeces are collected in a moveable box or basket (d). This container, when almost full, can be moved to the side and an empty one is put below the drop-hole (not visible in this cross-section). The vault is big enough to keep both containers and the full box will stay until sanitisation has taken place.

Numerous toilet models exist, with the double-vault dehydration toilet with urine-diversion being the 'original' one. The urine-diversion double-vault toilet originated from the model of the Vietnamese dry toilet. Similar to the double-vault composting toilet the dehydration toilet vaults are used alternating and excreta are stored until safe for re-use. The double-vault dehydration toilet should be built entirely above ground to allow easy access to the collection chambers (Werner et al. 2006).

For better understanding of how urine diversion works, Figure 14 shows different models of prefabricated urine diverting toilet seats/ slaps. A) squatting pan with urine diversion, e.g. used in China. This version is made of plastic and is mass-produced in China. The large opening is the drop-hole for faeces. The pan slopes towards the smaller opening and that way urine is collected. The lid of the squatting pan can be pushed aside and closed with the foot. B) Urine diverting slab toilet, e.g. used in India; C) Single Flush Urine Diversion Toilet, Sweden; D) Double Flush Urine Diversion Toilet, Sweden; E) Urine diverting insert to a bucket toilet:

Figure 14: Urine diversion slabs and seats (Heeb et al. 2006)

As men sometimes do not want to sit down when urinating, a problem arises because urine diversion toilets are designed for sitters or squatters. This can be overcome by providing a urinal.

Dehydrating toilets need a reasonable amount of user care and training and ongoing technical support are normally needed if this technology is applied

Interface between toilet and collection service

Faeces may not be reused on-site. If on-site use or soil infiltration of urine is not possible, or if urine can be sold as fertiliser, a collection scheme is advisable. Thus the interface between toilet and collection service becomes a critical point.

The urine can be stored on-site until collection in jerry cans or plastic containers of every size. Metal barrels should be avoided as they easily corrode in contact with urine (Kvarnström et al. 2006). Another possibility is to direct the urine from one or more toilets into a larger tank which can be accessed and emptied by a vacuum tanker for example. Faeces collection might profit from the use of moveable containers instead of fixed vaults. Accessibility and size of the containers are a critical point. The smaller the containers are the more often they will have to be emptied, but the easier it is to lift them. Easy access is also important for user satisfaction if toilets are operated by the householders themselves. According to Jönsson and Vinnerås (2007), the main factors for achieving high acceptance of a dry toilet system proved to be whether it had any problems with flies and how difficult the users experienced that emptying of the collected faecal material was. Both problems can be overcome when small containers with a high frequency of emptying are used. For the collecting service, the access should be designed in a way that the chambers can be emptied from the street side.

3.5.5 Dry Sanitation: Biolatrine

"The biolatrine is in principle the centre part of a sanitary biogas unit for safe human faeces disposal, degrading the excreta anaerobically, thus producing biogas and digested substrate that may be utilised as fertiliser." (GATE GTZ 2000). Almost all kinds of organic wastes can furthermore be digested, provided the processes for treatment and disposal or reuse of these wastes are well considered in the initial design of treatment facilities (Butare, Kaaya 1996). In rural areas small biogas plants are popular for the digestion of animal dung and human waste to provide energy for cooking, lighting, etc. In urban areas, biolatrines mainly aim at the sanitary aspect, e.g. clean toilets with low maintenance demand, rather than at high gas productivity. They are usually designed as integrated fixed-dome biogas plants, where several latrines can be installed around a dome. These latrines can be operated with or without flush-water. For the system design and operation, two different strategies have been developed, the first one with a very short hydraulic retention time (HRT) of 1-3 days, where the digesters have roughly the same functions like a septic tank plus biogas production, the second with a HRT of at least 30 days (GATE GTZ 2000). The BIOSAN latrine (Makhanu, Waswa 2006) is an example for the latter. It has been developed by CAMARTEC in Arusha, Tanzania, as described by (Sasse et al. 1991), (Butare 1996) and (GATE GTZ 2000). This sanitary biogas unit consists of a pit-latrine, digester, gas chambers and delivery systems, as represented in Figure 15.

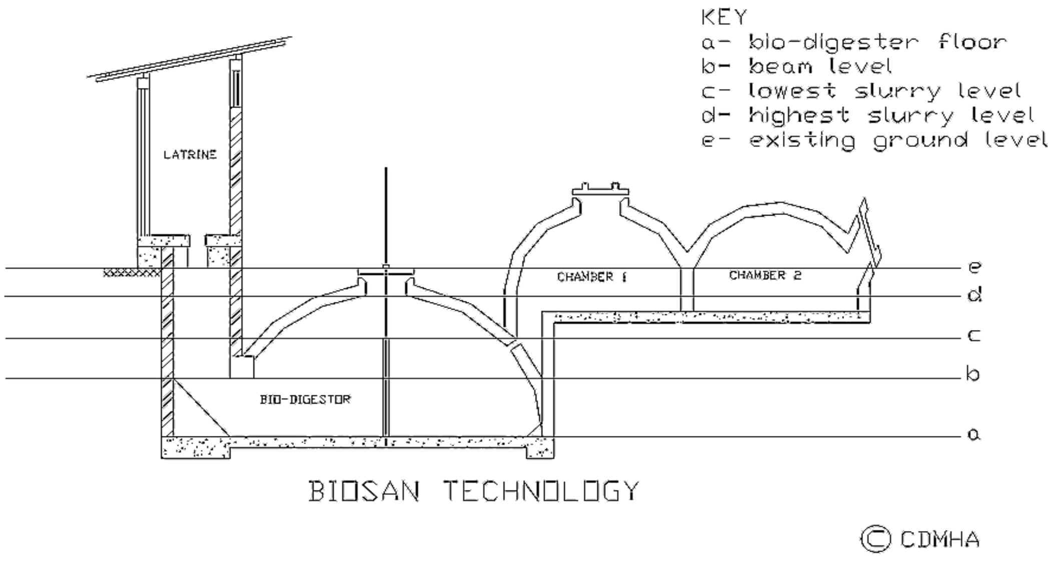

Figure 15: Sanitary biogas unit (Makhanu, Waswa 2006)

Human excreta is the major input in the system, and enters the system through the pit-latrine. The urine will normally provide sufficient liquid for the substrate to be able to flow. The excreta moves by gravity into the first compartment and then overflows over the baffle wall into the second compartment. The digester is emptied after filling up. The system starts generating biogas when the slurry level creates a seal in the pit-latrine. The BIOSAN latrine may only be an appropriate solution if at least 25 people are connected to its use, making the technology very appropriate for public toilets in crowded areas or for public and learning institutions (Makhanu, Waswa 2006).

The excreta of 25 people normally produce an average of about 1 m³ of biogas per day, representing the approximate cooking energy demand of one household. Speaking of institutions with 500 or more attendants, the produced biogas may supply sufficient energy for a canteen (GATE GTZ 2000).

The bio-digestion process works best under a restricted range of conditions. The gas production potential of a certain substrate is high when organic matter content is high and the C:N ratio ranges from 20:1 to 40:1.The minimum temperature is about 15°C. The maximum is 45°C and the optimum range is 30-35°C. Even more important than the temperature is temperature stability. Changes of more than 2°C per day are harmful to the process, since the bacteria adapt rapidly to prevailing conditions and must readapt when the temperature changes. Acidity is also a significant constraint, with the optimum ph range 6-8. Methane-producing bacteria are negatively affected by acidity outside these limits. (Sasse et al. 1991).

In anaerobic processing in developed countries, the digesters are often artificially heated to allow fast treatment of large volumes of waste. This is an expensive exercise, and in developing countries bio-digesters normally depend on natural prevailing conditions to establish the temperature (Butare, Kaaya 1996). Thus, the process is operating at ambient or mesophilic temperatures and is difficult to control. Temperature and retention time therefore vary and sufficient pathogen reduction is difficult to achieve even at long retention times (Heeb et al. 2006). For any system type post-treatment of the slurry, such as by sludge drying beds, thermophilic co-composting with organic bulking material or extended storage, is required to achieve the hygienic quality compatible with the WHO guideline value (WHO 2006). However, in many areas the slurry is re-used in agriculture without any post-treatment, which can only be recommended if slurry is applied to non-food crops, to crops that are never eaten raw or to trees or shrubs. Fresh slurry should never be exposed to people directly and application has to be accompanied by health protection measures.

Advantages:

- Biolatrines can be operated both at individual household level and as communal facilities (Vest, Bosch 2005)
- They do not require water for their operation (GATE GTZ 2000)
- Biogas can be used for energy purposes and the slurry can be applied to the soil as fertiliser after post-treatment (Butare 1996)
- Stabilisation and volume reduction of fresh sludge (Klingel et al. 2002)
- Improvement of hygienic conditions through reduction of pathogens, worm eggs and flies (Rose 1999)
- Reduction of cooking costs by a partial substitution of firewood. This aspect is also of significant importance due to the overuse of natural wood resources, occurring in the majority of the developing countries. (GATE GTZ 2000)
- Reduction of workload, mainly for women, in firewood collection and cooking (Rose 1999)
- The BIOSAN latrine can be operated without major maintenance demand for 10-20 years (Makhanu, Waswa 2006)
- Construction is possible through locally available materials (Makhanu, Waswa 2006)

Disadvantages:

- In the context of dry sanitation concepts, biolatrines are the most cost-intensive solution concerning investment costs (Vest, Bosch 2005)
- Post-treatment of slurry is necessary (WHO 2006)
- Operation requirements are quite considerable (Klingel et al. 2002)

Interface between toilet and collection service

The slurry chamber should be easily accessible for vacuum trucks to facilitate emptying. The opening of the digester-chamber should also be accessible as from time to time solidified sludge has to be removed.

3.6 Part B: Collection and Transport

Pit-latrines, biolatrines and septic tanks produce faecal sludge of different qualities which has to be collected. Composting toilets will, if they are properly managed, produce sanitised compost and dehydrating toilets produce dried faecal matter and urine. A transportation system is needed when excreta and greywater can not be treated, deposited or used onsite. Sound organisation and management of transportation systems will determine the sustainability and continuity of the entire sanitation system. Transportation systems can be divided into infrastructure base systems, such as sewer networks, or logistic management using regular transportation means such as trucks, vacuum tankers, carts, and tricycles. Sewer networks require sufficient water to transport excreta effectively. Furthermore, sewerage is only appropriate if soil conditions are favourable and financial and institutional capacity is available. Factors that influence the design and applicability of the transport system include the amount of waste generated, housing density, street access, haul distance, road conditions, road gradient, traffic type, and the cost of labour and fuel. A house-to-house collector may transport material directly to its destination. However, transfer becomes necessary when distances increase and direct transport is no longer economically feasible or when the destination can only be reached with a different means of transport. (NWP 2006)

O&M tasks and responsibilities are not further described for collection and transport facilities, as the scope of this thesis is too limited for that. For O&M of most of the described collection and transport facilities refer to Brikké and Bredero (2003).

3.6.1 Wastewater Collection and Transport

Simplified (condominium) sewers

A sewer system receiving unsettled domestic wastewaters. Sewer design is based on the same hydraulic principles as used for conventional sewerage, but without any of the conservative rules-of-thumb and safety factors used for the latter. Simplified sewerage uses a minimum sewer diameter of 100 mm. Self cleaning is ensured by using a minimum peak-flow of 1.5 l/s. This results in minimum sewer gradients that are shallow but satisfactory. Simple junction boxes are used rather than manhole. Simplified sewerage costs by 20 - 50% of the cost of conventional sewerage. (Mara et al. 2006)

Settled (Small bore) sewers

A sewer system receiving the solids-free effluent from a septic tank. The hydraulic design is fundamentally different from that used for conventional and simplified sewerage (Mara et al. 2006). Settled sewerage is is designed to receive only the liquid portion of household wastewater. Solids are removed in an interceptor tank (septic tank) which is part of household connection. The clarified effluent flows by gravity into the sewers, which are designed as gravity fluid conduits. The settled sewerage costs are quite low in comparison to conventional sewerage mainly due to shallow excavation depths, use of small diameter pipe work (commonly 75-100 mm PVC) and simple inspection chambers. (Abdel-Halim, Rosenwinkel 2005)

Conventional sewerage

Conventional sewerage is not recommended for peri-urban areas and small towns, as it is too expensive. However, for city-centres and high-value commercial and industrial areas it might be applicable (Mara et al. 2006).

3.6.2 Faecal Sludge Collection and Transport

Large vacuum tankers, truck or cart mounted

The classical technology for emptying of septic tanks or pits is by suction with a vacuum pump. A hose is introduced in the vault and the content is sucked out. Sometimes stirring of the pit content and addition of water prior to suction may be required for loosening of the sediment layer. Sludge removal by suction pump largely minimises the direct contact of the workers with the sludge and is therefore the safest technique available. The pump is usually connected to a truck-mounted tank of variable capacity (1 to 10 m^3). In this way the truck can access the plot, empty the facility and then directly transport the sludge to the disposal or treatment site. This type of equipment is the same that is used in industrialised countries and is rather expensive. In developing countries the tanks are often mounted on carts pulled by tractor or animals. This version is considerably cheaper and technically equivalent to truck mounted systems. The disadvantage is the reduced mobility and action radiant due to the slower speed. (Klingel et al. 2002)

Mini vacuum tugs

Households in urban centres or in informal dense settlements of developing countries are often located in very narrow lanes that are inaccessible to large vehicles. Large suction units as described above are useless in this kind of situation and a large part of the households can therefore not be serviced with this equipment. For this reason smaller units have been developed in various places, e.g. by UN-Habitat in Nairobi[23] and by WASTE in Dar Es Salaam[24]. This equipment consists of smaller tanks (200-500 l) and a motor or hand-driven vacuum pump. It can be hand-pushed or motor-driven. These units are not appropriate to transport sludge over longer distances. Thus they need to be combined with truck mounted tankers or with intermediate storage and transportation tanks transported by hook-lift trucks. The ideal solution in many cases would be to combine large equipment for the normal situations with smaller units for the areas difficult to access (Klingel et al. 2002). However, experiences with these intermediate technologies, have rarely extended beyond the stage of external support to become viable businesses. Whereas such technologies should not be dismissed, their successes have been limited (MIT 22.10.2003).

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[23] The ‘Vacutug’ system - refer to www.hq.unhabitat.org

[24] The ’MAPET’ system - refer to Muller (1997)

Manual emptying

Manual vault emptying will still be the final option when the use of vacuum pumps is excluded for certain reasons. Manual emptying can only be acceptable if two points are respected: The health risk to workers must be minimised and the transport to the disposal site must be organised. Both are much more organisational than technical problems. Good hygiene and protection clothes reduce the health risks. Sludge can be transported by carts or in buckets to the disposal site. However, it can be especially difficult to make independent workers bringing all the sludge to the desired site. Usually they earn their money from the fees emptying of vaults and not for transportation of sludge. Therefore they tend to dispose the sludge close to the emptying site in drains, fields or on the street. The only way to achieve that workers bring the sludge to designed site may be to provide appropriate incentive systems. Incentive systems should include both rewards for taking the desired actions and sanctions against harmful actions (Klingel et al. 2002).

3.6.3 Faeces and Urine Transport and Collection

If faeces and urine from dehydrating and composting toilets are not to be reused on-site they should ideally be transported short distances to decentralised secondary-treatment facilities.

Cartage system

Tricycles and push carts can be used to transport containers and oil drums containing urine or excreta. Push carts and tricycles (pedal or motorised) have the advantage that they can access small streets. Tricycles can speed up the collection operation and increase the radius of the collection in urban areas, transporting the containers to transfer stations or to community treatment facilities. From transfer stations, urine and excreta can be loaded onto trucks or tractors, which can haul a larger volume over a long distance. Tricycles can collect door to door, although urine can also be collected in larger containers serving a number of houses (NWP 2006). Applying conditions are:

- Pushcarts and tricycles are especially appropriate in flat urban areas, with access roads.
- Pushcarts and tricycles are not appropriate for collecting large volumes (> 300 litre, > 300 kg) or for longer distances.
- Operators require training and regulation.

The use of trucks and tractors for transporting containers is also possible if the settlement structure and financial capacity allow for it.

Tank systems with pumping facility

Vacuum trucks or smaller tank-vehicles equipped with vacuum pump technology (hand pumps or motorised) can be used for emptying larger urine storage tanks. Storage tanks and motorised transport are expensive and both tank size and emptying frequency are important factors. Thus, for economic reasons, urine tanks should ideally have equal capacity to the tanks of emptying vehicles. This way the vehicle can empty the tank at once and transport and storage costs are optimised.

Pipes

Furthermore, transport of urine in small-bore pipes, together with greywater, could be an alternative option in some cases but may be more capital cost intensive (Münch, Mayumbelo 2007).

Case study on logistic aspects of Ecosan

Slob (2005) conducted a case study on logistic aspects of Ecosan (here: dehydration and composting toilets) in urban areas in a low-income community in Delhi, India. A financial estimation of different collection systems was done and the recommendations given for the specific setting are as follows:

For urine collection, collection with a tractor trolley combination equipped with a pump is the most effective and efficient system for large-scale collection. For faeces collection, the use of a household double vault system and collection with a simple tricycle is advised: the tricycles transport the faeces to a transfer trolley located nearby the collection area and secondary transport takes place with a tractor.

Advice is also given by Slob (2005) how initial investments for a limited participation level of 100 households can be kept small. For urine transport the initial investments required for purchasing equipment are around € 900. For faeces transport the work can be done within two days at that participation level and it is advised to hire a tractor with trolley and driver and a few daily labourers operating simple tricycles or wheelbarrows instead of buying the necessary equipment. This way total yearly costs for faeces are limited to around € 75 initially.

In chapter 4.6.2 (Financial Aspects and Cost Estimates of Urban/ Peri-Urban Ecosan) financial aspects of large-scale urine harvesting will be discussed, as urine collection and transport is the major challenge for the logistics of urine-diverting Ecosan in an urban setting. This is due to the large quantities of urine produced (in comparison to the relatively small amounts of dried faeces).

3.7 Part C: Treatment

For the treatment of the identified flows (faeces, FS, urine and greywater) numerous methods exist, with technical solutions ranging from the high-end market down to low-cost options. The focus here is on the low-cost solutions, as the sanitation challenge is basically to be met in poor areas.

In tropical areas (where the ROSA project will be implemented) solar radiation is high and as it is ‘for free’, many low-cost treatment methods rely on the pathogen killing effects of UV radiation, heat generation and desiccation. But also anaerobic treatment methods will profit from the high solar radiation as the generated heat favours the anaerobic processes.

3.7.1 Treatment of Faeces

A secondary treatment is necessary if the criteria for on-site treatment described in Table 4 on page 25 cannot be fulfilled. Especially Ascaris eggs turn out to be particularly resilient to primary treatment. Collected matter can be treated on the municipal level under supervised conditions. The simplest forms of secondary treatment would be a certain storage period. The guidelines from Table 4 should be regarded when storage treatment is favoured. Table 5 gives recommendations for further processes of secondary treatment. In Appendix B a flowchart for the safe reuse of faeces after primary on-site treatment is given. The flowchart is making use of simple yes/ no decisions to guide the user towards the optimal treatment methods It is based on the WHO guidelines (2006) and was translated and adapted from Sanabria (2007).

Table 5: Additional treatments for excreta and faecal sludge off-site, at collection and treatment stations from large-scale systems (municipal level) [a]

Treatment	Criteria	Comment
Alkaline treatment	pH >9 during >6 months	Temperature> 35 °C and/or moisture< 25%.Lower pH and/or wetter material will prolong the elimination time.
Composting	Temperature>50 °C for >1 week	Minimum requirement. Longer time needed if temperature requirement cannot be ensured.
Incineration	Fully incinerated (<10% carbon in ash)	

[a] Run in batch mode without addition of new material.

Source: (WHO 2006)

For composting it is has to be kept in mind, that aerobic decomposition in composting can take place in four temperature zones, while there is rapid pathogen reduction in the thermophilic zone only (Heeb et al. 2006):

- Below 5°C is **biological zero –** little to no active processing takes place
- From 6°C to 20°C, **psychorophilic** (ambient) processing (mouldering) takes place.
- From 21°C to 45°C, **mesophilic** bacteria are dominant. These are the typical bacteria in a composting toilet.
- From 46°C to 71°C**, thermophilic** bacteria take over, and push the process to the limit.

Secondary composting is a good way to sanitise the material, as thermophilic conditions can be achieved in a professional composting plant. Organic household waste added to the process can lead to substantial increase in temperature (Starkl et al. 2005). Another treatment option is vermicomposting, where worms transform organic material in their digestion tract until they are plant-available and destroy pathogens. These earthworms furthermore provide deep aeration and prevent compaction of the material. However, the following aspects have to be regarded (Heeb et al. 2006):

- Earthworms do not survive temperature above 38°C
- High moisture levels are needed
- No acidic soils
- No mixing, tumbling or chopping of material
- Longer retention times than thermophilic composting to get safe product

In the case that nobody wants to reuse the faeces, it can be buried in a safe place. Guness, Pillay et al. (2006) undertook a study on the pollution-potential of buried faecal material from urine-diversion toilets. The study indicates a potential for groundwater contamination through nutrients and pathogens over extended periods of time or if excessive leaching occurs, should the groundwater table be in close proximity to the buried waste, i.e. areas with a high groundwater table. Hence subsurface deposition of processed faecal matter can only be recommended if environmental conditions are favourable.

3.7.2 Treatment of Faecal Sludge

Storage time is the principal factor to kill off organisms in drop-and-store systems, where FS is hold back in septic tanks or pits. In most cases sanitisation in these systems is poor as pits/ septic tanks are used continuously and there is no storage time without the addition of fresh excreta. Septic tanks provide primary treatment trough settlement of solids and anaerobic digestion. The extent of treatment in conventional on-site facilities is hardly ever sufficient to allow for instant reuse. However, if the criteria in Table 4 on page 25 can be fulfilled, in a double-pit VIP operated in batch mode for example, the processed FS can be reused safely according to the WHO recommendations (see chapter 3.3.3: Containment and Treatment of Excreta in Ecosan on-Site Facilities). The sludge from biogas systems is stabilised and may be sanitised depending on factors like retention time and temperature; however, as temperature is difficult to control in low-cost non-heated bio-digesters, further treatment is advisable.

FS from on-site sanitation without adequate storage time may contain high numbers of pathogens and thus secondary treatment is necessary. Knowledge about low-cost treatment technologies is limited as research for technologies adapted to conditions in developing countries always has been focussed on wastewater treatment exclusively (Klingel et al. 2002). Sludge treatment involves different treatment steps, and available techniques can be combined in various ways depending on the local conditions and the treatment objectives. Figure 16 depicts some FS treatment processes and options which might be suitable for low- or middle-income countries (Ingallinella et al. 2002).

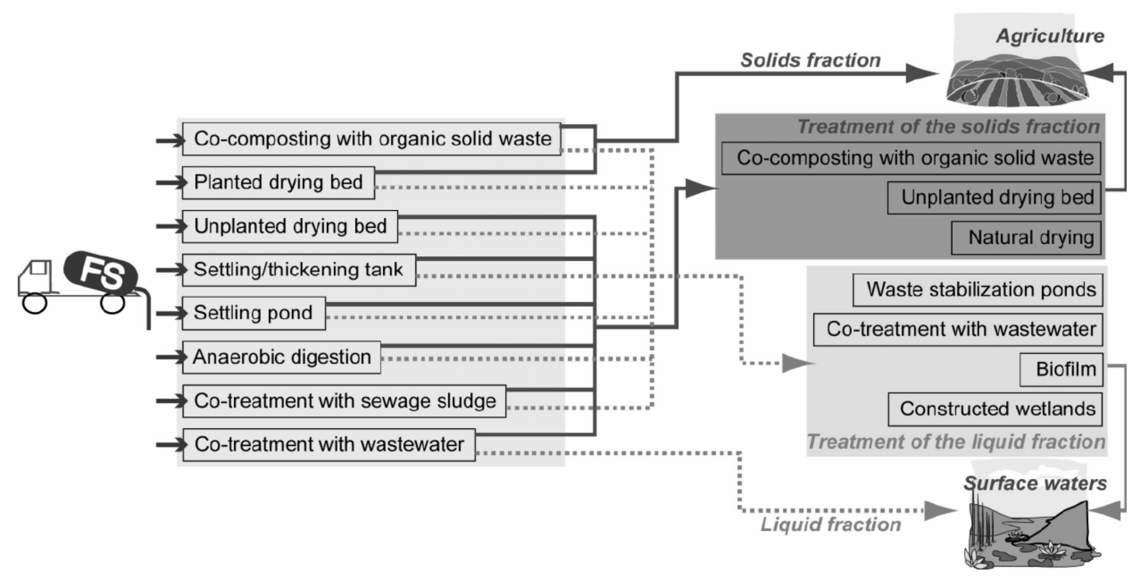

Figure 16: Low-cost faecal sludge treatment options (Ingallinella et al. 2002)

FS cannot be treated like wastewater because its pollutant concentrations are too high. Furthermore it cannot be landfilled or treated like solid waste because its moisture content is too high. The first stage of FS treatment thus mostly involves the stabilisation of the sludge and the separation of the solid phase and the liquid phase. Following the liquid part can be treated specifically, usually with wastewater treatment technologies. Post treatment of the solid part assures the necessary quality corresponding to the treatment goals. When solids are reused for food crop production, the treatment has to provide hygienic safety. If solids will be used for non-food crops, be disposed off, or used for other purposes, the treatment basically has to provide adequate consistency of the solids. Post treatment of liquid effluents from primary treatment assures that the final effluent can be discharged into surface waters without negative impact on environment and public health (Klingel et al. 2002).

The treatment recommendations for faeces given in Table 5 on page 42 can also be applied to FS treatment methods, according to the WHO (WHO 2006). Simple, low-cost methods for secondary treatment of FS should be favoured in order to aim for financial sustainability. In tropical areas planted FS drying beds have proven to be a good method to mineralise and sanitise sludges from on-site sanitation facilities (Heinß et al. 2003). The helminth egg reduction achieved in a 12 month period (WHO 2006) is not very high, but as planted sludge drying beds are usually operated for a 5 to 10 year period the product is sanitised completely (GTZ 2005).

If there is demand for high quality fertilisers and soil conditioners in the project area, more sophisticated methods in terms of compost quality, like co-composting with organic waste could be financially interesting through the sale of compost. For this purpose the biological fraction of solid waste has to be collected and separated (or ideally collected after household separation).

Anaerobic digestion offers the additional benefit of gas production, which can safe fuel wood and thus work-time mainly for women in wood collection and cooking (Rose 1999). Furthermore deforestation, which is a huge problem to many societies, can be decreased. Anaerobic digestion can not be used as a single treatment method though; the slurry needs further treatment to obtain a safe material (Parr 2006).

According to Parkinson and Tayler (2003), decentralised approaches to FS collection and disposal are particularly appropriate for peri-urban areas, as they reduce haulage distances and thus reduce the cost of transportation. In some cases, the investment may require little more than improvements to existing informal wastewater collection systems and the introduction of an appropriate form of treatment prior to disposal or re-use. Although economies of scale mean that decentralised treatment facilities will tend to have a higher cost per person served than centralised facilities, the incremental increase in per capita cost is likely to be fairly small where unsophisticated technologies are used.

3.7.3 Treatment of Urine

Urine contains few pathogens and can be regarded as “safe” from the hygiene point of view. The only risk arises if faeces, possibly containing pathogens, contaminate the urine by misplacement in the urine bowl (Kvarnström et al. 2006), or in areas where *Schistosoma haematobium* is prevalent (WHO 2006). Urine is ideally stored undiluted as the pH then rises reasonably high; this will render urine safe for use in agriculture after one month storage. When stored, urea is degraded to ammonium in the presence of urease and thus pH levels rise to around 9. The elevated pH, ammonia content and temperature will affect the die-off of pathogens (Jönsson et al. 2004). When crops are intended for the household’s own consumption, urine can be used directly. It is recommended, however, that there should be 1 month between urine application and harvesting if crops are eaten raw. When urine is collected from households and transported for re-use in agriculture, the recommended storage time at temperatures of 4–20 °C varies between 1 and 6 months depending on the type of crop to be fertilised. The following guidelines for urine storage-time are given by the WHO (2006):

Table 6: Recommended guideline storage time for urine mixture[a] based on estimated pathogen content[b] and recommended crop for larger system[c]

Storage temperature [°C]	Storage time	Possible pathogens in the urine mixture after storage	Recommended crops
4	≥1 month	Viruses, protozoa	Food and fodder crops that are to be processed
4	≥6 months	Viruses	Food crops that are to be processed, fodder crops[d]
20	≥1 month	Viruses	Food crops that are to be processed, fodder crops[d]
20	≥6 months	Probably none	All crops[e]

[a] Urine or urine and water. When diluted, it is assumed that the urine mixture has a pH of at least 8.8 and a nitrogen concentration of at least 1 g/l.

[b] Gram-positive bacteria and spore-forming bacteria are not included in the underlying risk assessment but are not normally recognized as a cause of any infections of concern.

[c] A larger system in this case is a system where the urine mixture is used to fertilize crops that will be consumed by individuals other than members of the household from whom the urine was collected.

[d] Not grasslands for production of fodder.

[e] For food crops that are consumed raw, it is recommended that the urine be applied at least one month before harvesting and that it be incorporated into the ground if the edible parts grow above the soil surface.

Source: (WHO 2006)

Apart from storage further treatment methods exist. They aim either at one or more of the following targets: hygienisation, volume reduction, stabilisation, P-recovery, N-recovery, nutrient removal or handling of micro-pollutants. A wide range of technical options is available to treat collected urine effectively, but none of these single options can accomplish all seven purposes. Furthermore, the only two treatment methods which have advanced beyond the laboratory stage are storage (hygienisation) and evaporation (volume reduction) (Maurer et al. 2006). As low-tech methods for evaporation are dependent on large amounts of acid to lower the pH level and hinder ammonia from evaporation, this is not an option yet.

3.7.4 Treatment of Greywater

Even where management of greywater consists of using it to water plants, to hold down dusts on roads, or simply allowing it to infiltrate the soil, the hazards posed by greywater are far less than those posed by human excreta or the lack of good hygiene (Sawyer et al. 2003). Greywater, while representing the largest fraction of the total wastewater flow, has only a low nutrient and pathogen content. Therefore, it can be treated by using simple techniques such as gravel filters, constructed wetlands or ponds. The effluent normally aimed for irrigation of agricultural crops in water-scarce regions, can also be used for groundwater recharge or industrial or urban reuse or discharged into surrounding watercourses (Werner et al. 2003).

Managing greywater can be made easier by water conservation measures as well as attention to the soaps, cleansers and other household chemicals used on a daily basis (Sawyer et al. 2003). If greywater is used for irrigation, liquid soaps containing K are preferred, since hard soaps often contain sodium, which increases the risk of soil salinisation (WHO 2006). The amount of greywater generated can be significantly reduced through:

- behavioural changes
- good maintenance of pipe and water taps
- the use of water-saving devices.

Although greywater does not generally present health concerns and will not pose significant pollution hazards if toxic products are not used, it is best to design a greywater system that prevents human contact and the potential for environmental contamination. The final discharge or use of the water determines the extent of treatment needed. Before discharge to open water bodies or use in irrigation or groundwater recharge, the treatment should safeguard the hygienic quality. Many treatment methods exist, however pre-treatment is necessary for every option to avoid clogging of the subsequent treatment step. It consists of a solid-liquid separation that reduces the amounts of particles and fat in the effluent.

Common options for pre-treatment are:

- septic tanks
- settling tanks
- ponds
- filter systems such as filter bags

Common options for secondary treatment are:

- Soil infiltration
- Drip irrigation
- Ponds
- Constructed wetlands
- Sand filters
- Bio filters
- Mulch beds and greywater gardens (WHO 2006)

3.8 Part D: Transport & Part E: Reuse

Transport

For transport of the recyclates, basically all local vehicles commonly used for transportation of goods can be used. Transport of sanitised urine and processed FS and faeces can for example happen by open trucks. However, some experts assume that customers buy the fertiliser and organise the transport (Münch, Mayumbelo 2007). If urine is to be reused, farmers will also need further urine storage of some form because N fertilisation is not carried out all year round. Urine poses the biggest (financial) challenge for transport and storage (see chapter 4.6.2: Financial Aspects and Cost Estimates of Urban/ Peri-Urban Ecosan). Treated greywater is normally transported by pipes.

Reuse

For resource efficiency it is important that the excreta are used close to the source of generation. This implies that sound sanitation planning must be coupled with sound urban planning if possibilities for reuse within city limits are desired for sanitation contexts. These possibilities could encompass, for example, support to urban agriculture and the use of urine in parks and soccer fields (Kvarnström et al. 2006). Furthermore could the soil conditioning and fertiliser value of sanitised faeces and urine reduce sanitation cost when sold (Sawyer et al. 2003).

Key Issues

The concept of the five steps (household facility – collection & transport – treatment – transport – reuse) of resource-oriented sanitation systems together with the different waste-flows, represent the material and environmental dimension of a sanitation system, for which O&M has to be planned for. Several sanitation facilities, commonly used in households of developing countries have been presented. More innovative solutions, which can render human excreta a safe product on the household level, have also been described. It has been highlighted under which conditions the different household facilities are adequate, and advantages and disadvantages of these technologies have been highlighted. The interface between toilet and collection service is a design criteria that has to be considered when planning for collection schemes. Different sanitation options lead to different waste-flows and collection, transport and treatment has to be designed accordingly. Faeces and urine which has been rendered safe for on-site reuse might still need collection and further treatment on a municipal scale. Off-site treatment processes and transportation possibilities for the different waste-flows have been presented and a general understanding of the requirements of each waste-flow has been given.

4 Operation and Maintenance

4.1 Background

4.1.1 Introduction

O&M of sanitation systems still receives much less attention than their design and construction (Sohail et al. 2001). Under the pressure to extend sanitation services to more people, the budget and staffing for O&M often get lower priority than for construction of new facilities. Among the consequences are non functioning services and installations and damage to the environment and people's health (Rottier, Ince 2003).

In the rush for reaching the MDGs for sanitation, it should never be forgotten that the provision of appropriate sanitation facilities alone will not lead to a sustained improvement of the situation. Facilities that break down, discharge sewage into the environment or simply are misused will help no one. Careful planning and the implementation of capable management structures are a precondition for the success of every large-scale intervention. Especially in the urban context, where mismanagement of facilities can lead to serious environmental and public health problems, institutionalised O&M arrangements are mandatory.

4.1.2 Definitions

Initially some terms have to be defined:

Operation:
Refers to the activities involved in the delivery of a service. This involves:

- the major operations required to use the service
- the correct handling of facilities by users to ensure the long life of the service (Sohail et al. 2001)

In the sanitation context, operation includes the planning and control of the collection, treatment and disposal or reuse of the waste flows. It also covers "the management of client and public relations, legal, personnel, commercial, and accounting functions." (IRC, WEDC 2002)

Maintenance:
Deals with the activities that keep the system in proper working condition, including management, cost recovery, repairs and preventive maintenance. The term maintenance covers:

- Crisis maintenance: maintenance undertaken only in response to breakdowns and/or public complaints, leading to poor service level, high O&M costs, faster wear and tear of equipment, and user's dissatisfaction.

- Preventive maintenance: maintenance activities undertaken in response to pre-scheduled systematic inspection, repair and replacement, leading to continuity in service level, O&M costs spread over time, extension of life-span of equipment, user's satisfaction and willingness to pay (Brikké 2000).
- Corrective maintenance: A procedure of repairing components or equipment as necessary either by on-site repair or by replacing individual elements in order to keep the system in proper operating condition. [25]

Management:
Management consists of (Brikké 2000):

- Planning
  Development of a strategy, objectives, and results to be reached
- Organisation
  Distribution of responsibilities and tasks
- Decision-making
  Taking decisions on regular activities, as mandated
- Coordination
  Harmonization of contacts between various actors, and communication
- Control
  Supervision and enforcement
- Monitoring
  Regular check and problem-solving

4.1.3 Operation and Maintenance in the Context of Sustainability

Problems with O&M are recognised as key constraints to a sustainable urban service. O&M represents the difference between the construction of an installation capable of meeting the needs of a community and its actual use by individual consumers (Sohail et al. 2001). For a sustainable sanitation impact, O&M is equally important as the hardware investments themselves. According to Brikké (2000), a service is sustainable when:

- It functions properly and is used.
- It provides the services for which it was planned, including: delivering the required quantity and quality of water; providing easy access to the service; providing service continuity and reliability; providing health and economic benefits; and in the case of sanitation, providing adequate sanitation access.
- It functions over a prolonged period of time, according to the designed life-cycle of the equipment.

[25] McGraw-Hill. Dictionary of Scientific and Technical Terms. Retrieved May 17, 2007, from Answers.com Web site: http://www.answers.com/topic/corrective-maintenance

- The management of the service involves the community (or the community itself manages the system); adopts a perspective that is sensitive to gender issues; establishes partnerships with local authorities; and involves the private sector as required.
- Its operation, maintenance, rehabilitation, replacement and administrative costs are covered at local level through user fees, or through alternative sustainable financial mechanisms.
- It can be operated and maintained at the local level with limited, but feasible, external support (e.g. technical assistance, training and monitoring).
- It has no harmful effects on the environment

To ensure sustainability not only during the project implementation phase, but for long time after the implementing agency left, O&M should be integrated into project development from the beginning (Brikké, Bredero 2003). For proper O&M its requirements have to be integrated in “planning, design, implementation, organisation and management in partnership between government, private agencies and residents” (IRC 1997).

According to Brikké (2000) sustainability and effective O&M rely on four interrelated factors (as seen in Figure 17): i) technical factors, ii) community factors, iii) environmental factors and iv) the legal and institutional framework (the frame in Figure 17). A financial dimension underlies all of these factors.

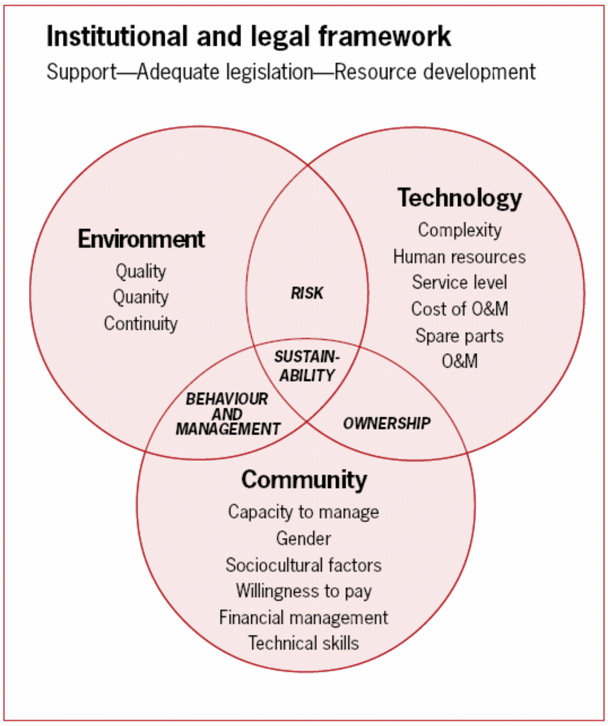

Figure 17: Factors which influence sustainability (Brikké 2000)

These factors will be analysed in detail later. However, environmental factors have already been discussed on a general basis in chapter 3 (Resource-Oriented Sanitation). Basically, there is a need to consider both emissions to different recipients (water, soil, and air), and also resource use by different sanitation systems during O&M. Moreover it is important to consider the quality of the treatment product for possible reuse (Kvarnström, Pettersens et al. 2004).

Sustainable O&M is furthermore influenced by a number of processes. These processes differ from factors since they focus on the approach and the methodology of working. Experience has shown that factors alone can not contribute to greater efficiency, effectiveness and sustainability. Nowadays it is realised that processes also have an important role to play. Among the processes can be listed the following (Brikké 2000):

- Demand from the community
- Responsiveness from the supporting institutions
- Participation of the community throughout the project phases
- Linking technology choice with O&M
- Integrated planning (sanitation, water, hygiene, environment)
- Planning with a gender perspective
- Decentralisation and transfer of responsibilities and resources
- Capacity-building at all levels
- Communication among stakeholders
- Public-private partnership (PPP)
- Co-responsibility between communities and municipalities

4.1.4 Knowledge Gaps

Knowledge gaps are principally in the field of Ecosan in cities/urban areas. Ecosan up to date was mainly a rural issue with experience in urban and peri-urban areas still being quite limited. So far little research has been done on the possibility and impacts of Ecosan in this context. Some even argue that technologies like dehydrating and composting toilets are not suitable for urban areas. Nonetheless, these technologies have several benefits – the most important one is of course the reduction of diseases. As many of the peri-urban areas have settlement structures which rather remind of rural than urban areas, dehydration and composting toilets could be a very appropriate solutions in conjunction with peri-urban agriculture. Tayler et al. (2003) recommend the use of these systems in urban areas only where ”(..) either there is already a strong tradition of the reuse of human excreta and/or there is an obvious potential to use wastes in agriculture.”

Especially logistical aspects of collection and transport of excreta to treatment stations are hardly addressed in current research. Questions like: what containers and vehicles should be used, should transport be done directly or is it more efficient to use transfer points have hardly been investigated yet. Only one document dealing explicitly with this issue could be found within the literature research; a master thesis on logistic aspects of Ecosan in an Indian context (Slob 2005). However, the operation of collection schemes for human excreta might profit from experiences out of the field of solid waste collection. “Solid waste offers interesting parallels for on-site sanitation but disaggregated demand remains a key challenge.”(Schaub-Jones et al. 2006). Disaggregated demand refers to the non-regular demand for emptying in contrary to the regular demand for solid waste collection.

In spite of the clear advantages of closed loop Ecosan approaches, the dearth of effective, affordable, and user friendly urine harvesting methods furthermore continues to be a major bottleneck for urine diverting Ecosan in urban settings. The volumes of dried faeces are relatively small and can be dealt with at intervals of several months at a time, whereas urine is a constant flow - and, unless it is disposed of non-ecologically in an on-site soak pit, the management of significant volumes of urine represents a major logistical, financial and cultural challenge (Sawyer 2005).

Even concerning conventional on-site sanitation only few experiences with local management models exist (Brocklehurst 2004). A strategic approach to O&M seems to be rare - in the context of decentralisation and community involvement responsibilities are often left unclear.

4.2 The Institutional- and Legal Framework

O&M of sanitation systems require a sound organisation and clear responsibilities. The legal- and institutional framework together with policies[26] ideally form an ‘enabling environment’ for that purpose. Without sound policies and legislation, there is little chance for significant development in the water and sanitation sector.

Policies governing the following issues are particularly important (Brikké 2000):

- the responsibilities of the communities and their ownership of the sanitation systems;
- technology choices affecting equipment standardisation and the procurement of spare parts;
- the role of the private sector;
- cost recovery mechanisms and fee structures;

[26] Policy is defined as “(…) a set of procedures, rules and allocation mechanisms that provide the basis for programmes and services. Policies set priorities and often allocate resources for their implementation” (Johanson, Kvarnström 2005)

- the role of government agencies and the scope of their support.

Unfortunately, in practice, sanitation policies are often not effectively implemented in developing countries. So far the existing institutional set-ups have not led to sustainable service provision for the majority of the peri-urban and low-income urban areas in most of the African cities. The often weak legal and institutional framework in many countries makes it difficult to implement and scale up sanitation solutions like Ecosan (Johanson, Kvarnström 2005).

4.2.1 Legislation

National governments are responsible for determining the roles of national agencies and the appropriate roles of the public, private and non-profit sectors in programme development, implementation and service delivery (WHO 2006). In many countries regional and communal authorities play an important role in legislation, too. Municipalities often have the authority to release by-laws, which regulate special issues on the local level.

According to the WHO (2006), legislation can facilitate technical incentives and financing mechanisms. In addition to that, legislation defines responsibilities and cooperation between relevant stakeholders, including the private sector, and appropriates financial resources for capacity building and training and for monitoring, implementation and maintenance. It provides a basis for the enforcement of standards for excreta and greywater collection, treatment and use. Effective laws, by-laws and regulations establish both incentives for complying and sanctions for not complying with the requirements. Often it may be sufficient to amend some existing laws, but sometimes new legislation is required. The following areas in legislation deserve attention to facilitate resource-oriented sanitation projects (WHO 2006):

- define institutional responsibilities or allocate new powers to existing bodies;
- establish roles and relationships between national and local government levels;
- create rights of access to and ownership of greywater and excreta, including public regulation of its use;
- establish land tenure;
- develop public health and agricultural legislation concerning greywater and excreta quality standards, produce restrictions, application methods, occupational health, food hygiene and other preventive measures linked to health-based targets as deemed relevant.

Ecosan often seems to fall outside of the existing regulatory framework. Among the reasons could be that the implementation of the Ecosan concept implies activities that touch more areas in society than conventional sanitation, hence making it subject to several different sets of regulations (Johanson, Kvarnström 2005). Sanitation regulation often is only attached to environment and public health issues. However in Ecosan there is also a need to focus on agricultural regulation, as the Ecosan objective is agricultural use of human excreta. A vast range of laws and regulations have possible influences on urban Ecosan programmes.

A conclusion from the 1st Conference on Ecosan in Nanning, 2001 was that "Ecosan is now ready to move beyond the small-scale demonstration project to the large-scale sustainable programme, especially in urban areas. To achieve this, by-laws and regulations may need to be adjusted and a system of incentives and sanctions devised." (Johanson, Kvarnström 2005)

4.2.2 Decentralisation[27]

At first some explanations on the decentralisation process should serve as the basis to understand the institutional context that is prevalent in many developing countries. Several countries are now implementing decentralisation policies, but institutional implications vary from one country to another. The main aim of a decentralisation process is greater efficiency, effectiveness and sustainability of public services. It is based on the assumption that local institutions can better respond to the needs of the population, and therefore adapt strategies and policies to the local context. Central-level institutions have to change their role from provider of services to that of coordinator, facilitator and support. This can be done by:

i) transfer of responsibilities from national to provincial/communal level

ii) 'deconcentration' of activities from national to local levels

iii) transfer of various activities to other actors such as NGOs and the private sector

Figure 18 describes this decentralisation process and its consequences. In **(1)**, the government is responsible for everything and the communities have no legal authority in such a centralised system. This system has proved to be inefficient, especially with regard to O&M of water and sanitation utilities in rural areas. In **(2)**, the communities have a certain degree of responsibility ranging from participation in labour to payment of services. The government still keeps an important role in the management of the system. This situation, which is now commonly accepted and implemented in many projects around the world, corresponds to community participation but not community management. In **(3)**, communities manage their system, but still rely on technical assistance and support. This situation corresponds to community management. In **(4)**, communities are autonomous; very few communities in the world have been able to sustain their activities in a completely autonomous way.

[27] Adapted from Brikké (2000)

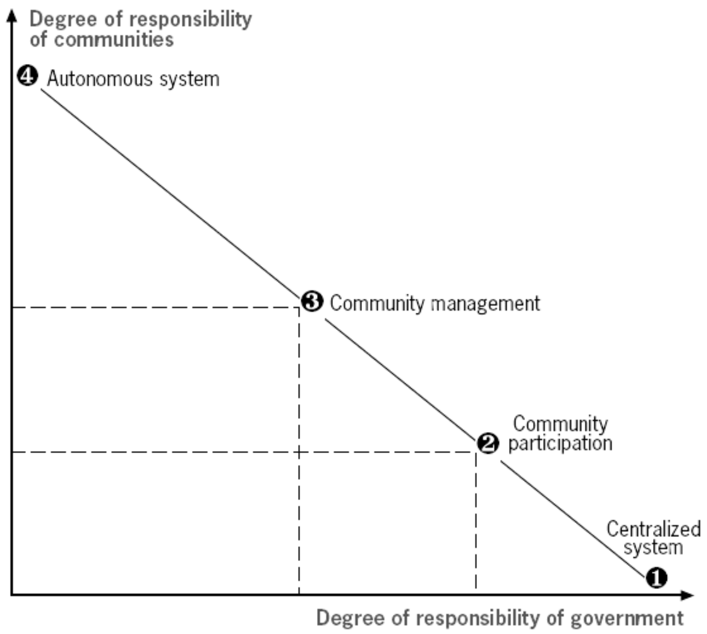

Figure 18: Substitution of responsibilities between government and community in a context of decentralisation (Brikké 2000)

The main consequence of this process from government to community level is that it increases the financial, operational, technical, and managerial burden at the local level, which communities do not have the capacity to carry. This process must therefore rely on accompanying measures such as:

- Building the capacity of communities in technical, financial and managerial terms.
- Reinforcing the role of local authorities in coordination with communities, and giving the technical and financial means to do so.
- Promoting the participation of local NGOs and small private firms (formal and informal) in the provision of services (technical assistance, training, repairs, spare parts provision).
- Changing the role of government institutions from provider of services to coordinator and facilitator.

The changing role of local institutions requires that their capacities be strengthened, but this is often not happening. For example in Uganda "the task of planning, enforcing regulations and allocating resources at the lower levels does not meet the goals that have been set in the process of decentralisation of responsibilities" (Johanson, Kvarnström 2005). Many local governmental institutions lack resources and institutional capacity to carry the burden the decentralisation process shouldered on them. Municipalities now more often see the importance to involve other institutions in service delivery. According to Sohail et al. (2002), governments must establish and sustain an environment in which communities can construct, operate and manage facilities.

Often non-governmental organisations (NGOs) are valuable counterparts in many planning and implementation activities and can fill gaps in knowledge and skills. The approach by indigenous, local NGOs for example, reflects cultural values and provides supportive functions, e.g. training and providing technical and managerial support. Sohail et al. (2001), who conducted a survey on O&M of sanitation systems in low-income settlements, state that “(…) these local NGOs knew what would work in that context and also had the patience and flexibility to not push for quick results.”

PPPs will play an important role in O&M. Participation of the private sector may range from simple maintenance tasks, to the operation, maintenance and management of the entire system under concession contracts (Brikké, Bredero 2003).

Communication between central and local levels of government, and between institutions, development agencies and all concerned stakeholders, will enhance the coordination of activities and implementation of policies. Effective information and monitoring systems rely on effective communication (Brikké 2000).

4.2.3 Stakeholders in Sanitation

It is obvious that the public sector agencies alone often fail in the supply of social and technical services in developing countries. “Apart from partnerships with the private sector, often the only sensible alternative for achieving sustainable improvements depends on the cooperation of various different stakeholders, including the local population and NGOs” (Bockelmann, Samol 2005). For this reason, the significance of the diverse local stakeholders should be seriously taken into account during the conception of urban sanitation management. In every sanitation project there are key stakeholders that have to be involved in the planning and implementation phases. The decisions and actions of the main actors and stakeholders determine an interrelated system.

Stakeholder Interests

A simple model to analyse relationships between on-site sanitation stakeholders, outlining three 'goods' that drive interaction between stakeholders is given by Schaub-Jones et al. (2006). The authors reviewed on-site sanitation improvement initiatives in five different African cities (Dar es Salaam, Durban, Maputo, Maseru and Nairobi). Three different, yet related, sets of 'goods' - the 'public good', the 'private good', and the 'provider's good' were identified:

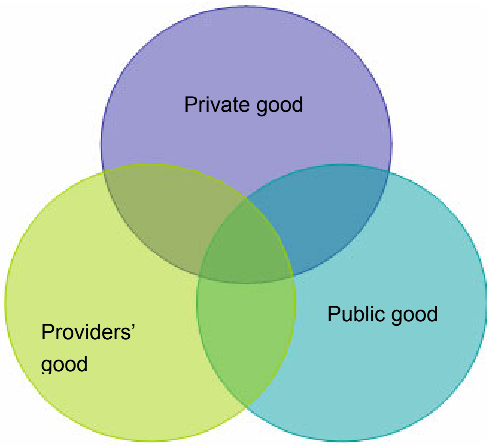

Figure 19: The three basic goods in stakeholder interaction (Schaub-Jones et al. 2006)

Households' and individuals' immediate interest is the **private good**. For on-site sanitation this is typically the use of a clean, comfortable and preferably private toilet, that does not smell and is affordable to access, build, use or maintain. In urban settings such toilets and facilities fill up and need emptying at some stage, and pit emptying is thus one service that households are willing to pay for to maintain their access to a facility.

The broader **public good**, which municipalities and other public bodies should be concerned with, includes protection of the environment and ensuring public health. This justifies the involvement of the public sector in what is otherwise an often private transaction between client and service provider. Such involvement is also diverse (there is a profusion of public bodies with an interest in sanitation) and ranges from support and subsidy to regulation and control.

Emptying services are delivered by a range of service providers, both manual and mechanical. For such service providers, the **provider's good** is a prime consideration: the need to be financially, politically and socially viable. (Schaub-Jones 2005)

<u>Stakeholders in Ecosan</u>

The number of different stakeholders that may be involved in a project can be quite large, depending on its type and scale, and will include very different individuals, groups, institutions etc. Both the interests and the constraints of the stakeholders can vary enormously and may not always be obvious to outsiders. It is therefore important to use a participatory approach in planning, so that the stakeholders can voice their motivating factors and the reservations they may have about the programme (Werner et al. 2003).

A number of potential stakeholders in Ecosan projects (of the type urban/ peri-urban upgrade) are given by Werner et al. (2003):

I. Users of sanitation facilities

- broad range of social conditions, from neighbourhoods of informal settlements, to detached single family homes, to multi-storey apartment or office blocks. Tenancy status plays an important role (see chapter 4.3.3: Tenure).

II. Users of the recyclates

- the households themselves (if they are involved in market gardening or urban agriculture, are willing to recuperate and use the grey water for other purposes, or to profit from the energy contained in their waste)
- groups or individuals engaged in agriculture, market gardening or landscaping (Drechsel et al. 2004) in or around urban areas; municipal authorities that wish to use the products on parkland etc.; organisations who wish to recover the energy contained in them or industries or small businesses who wish to reuse grey water or rainwater as service water

III. Community based organisations (CBOs) and self-help groups

IV. NGOs

V. Local authorities

- ranging from local to regional and national governments
- possibly actively participate in all steps
- many different authorities, with responsibilities in various areas (including water resources management, water supply and wastewater treatment, public health, irrigation, agriculture, forestry and town planning) may participate

VI. Service providers

- are of great importance in an urban context
- consultants who facilitate the process, and help establish the current sanitary situation
- consultant engineers specialised in the implementation of Ecosan technologies
- construction companies or manufacturers of prefabricated parts of the sanitary system
- businesses specialised in the collection, treatment, storage and transport of the recyclates, as well as in marketing them to the end users
- purely private businesses or part of a public institution or company, for example the local water suppliers may assume responsibility for the operation of the system

VII. Developers and investors

VIII. Financial institutions

IX. Research institutions

Stakeholders in sanitation differ in each city, so they need to be identified in the local context. The relevance of a certain stakeholder is dependent on both the type of project as well as on the project phase, with their roles and tasks varying.

4.2.4 Roles and Responsibilities

According to Tayler et al. (2003), the starting point for agreement on roles and responsibilities is recognition that sanitation services are often provided through more or less hierarchical systems, the components of which are linked so that performance at one level of the system depends on the services provided at other levels. The authors clearly illustrate this point with sewerage which normally includes the following:

- household facilities (WC, washing facilities, etc), connected to
- tertiary or street sewers, which in turn connect to
- secondary or collector sewers, serving local neighbourhoods and larger districts. In centralised schemes these connect to
- primary facilities, trunk sewers and sewage treatment facilities.

While the hierarchy may not be so obvious for other services, like for on-site facilities, it is usually there. On-site facilities have to be emptied and excreta have to be treated at a higher level, for example. Tayler et al. (2003) say that once this hierarchy is recognised it is possible to match roles and responsibilities to the interest and abilities of the various stakeholder groups and organisations using the following broad guidelines:

- Households should normally be responsible for managing facilities within their plot boundaries (as is normally the case already)
- CBOs, ward councillors, local NGOs, local entrepreneurs and local branches of municipal government and/or specialist service providers may be involved in the management of relatively simple local systems. Their direct interest in the functioning of these services means that they may carry out management tasks more effectively than would a remote government department.
- Larger more formally structured organisations will be required to manage higher-order services. Most will be government organisations, although recent years have seen increased interest in the involvement of the private sector in the management of municipal services.

The downside of this unbundling is that it often leads to fragmented responsibilities and thus creates an increased need for effective coordination between different stakeholders. Indeed lack of coordination between the various individuals, groups and organisations is often one of the biggest obstacles to the introduction of improved services. Thus, in many situations the priority will be to improve coordination between the various stakeholders, rather than to encourage further unbundling of responsibilities.

In Table 7 on the next page possible roles of stakeholders in O&M of Ecosan are presented. These, however depend on the local context and on the chosen management model as will be described later in chapter 4.5 (Management Options).

Key Issue

Appropriate legislation on national and local level is very important to create an environment in which roles and responsibilities can be determined. Current sanitation regulation is often attached to environment and public health issues. However, agricultural legislation can have implications for resource-oriented sanitation and must be considered and eventually adapted. The institutional framework has to be seen in the context of decentralisation. Local governments are seldom capable of providing adequate services and thus have to create an environment which facilitates the participation of the community and other stakeholders. Local authority's role as a coordinator of stakeholder involvement is still important. Numerous different stakeholders can play a role in O&M - the key-stakeholders have to be assessed and need to participate already in the planning and implementation stage. Three basic goods can be identified to express stakeholder interests in sanitation: the private good, the public good and the provider's good. Roles and responsibilities in O&M should reflect the level of the system (household, neighbourhood, ward, city, etc.). The critical point in having a large set of stakeholders is the fragmentation of responsibilities, thus, effective coordination has to be seen as uttermost important for sustainability.

Table 7: Possible roles of actors in O&M

Actors/group	Possible role in O&M of actors	Degree of involvement
Users of the sanitation facilities	– Maintenance of the on-site facilities (cleaning, smaller repairs, etc.) – Operation of the on-site facilities – Collection, treatment, storage and transport of the recyclates [a]	Major
Users of the recyclates	– Collection, treatment, transport and storage of recyclates	Little
CBOs; self-help groups	– Supply the workers for the maintenance and operation of the facilities, or for the collection, treatment, post-treatment and marketing of the recyclates, possibly developing into small scale service providers over time. – Training / advice to users and service providers	Major
NGOs	– Actively involved in promotion and raising awareness – Consultative role offering their experience and advice – Provision of funding – Training / advice to users and service providers	Medium to major
Local authorities and governmental institutions	– Maintenance and replacement of facilities – Direct service provision by government on a commercial basis, under contracts by individual or groups of stakeholders. – Reuse of the recyclates in municipal parks etc. – Guarantee that the system corresponds with the legislative norms, or to adapt these norms accordingly (e.g. by-law development and enforcement) – Monitor and control hygienic and environmental standards – Information dissemination and capacity-building to help generate understanding of stakeholder responsibilities – Provision of advice and support services to local service providers or contract service providers – Training / advice and technical assistance for the users	Major
National governmental institutions	– Set and adapt policy and legislation – Mobilise funding	Little
Service providers	– Maintenance and replacement – Training / advice to users – Collecting, transporting and possibly treating the recyclates before marketing them	Major
Research institutions	– Depending on the availability of research funds and the interests of the institution – Providing inputs on certain specialist issues – Environmental and health surveys/ monitoring	Little to medium

[a] In the implementation phase these tasks may be carried out by the users, but more usually this will be carried out by local authorities or a service provider.

Adapted from: (Werner et al. 2003)

4.3 Community Framework Conditions

At first the term community has to be defined. In this thesis the definition is adapted from Anschütz (1996). Community is defined as a group of users of a service who live in the same area and have access to, and use, the same service. This seems to be a practical definition of community which avoids getting caught up in the social and cultural meanings of the concept of community. However, it is easier to stimulate the participation of people, when they share cultural and religious ideas, have similar socio-economic interests and have some form of organisation, i.e. when there is some sense of `community' among them.

4.3.1 Community Participation

"Operation and Maintenance functions can be illustrated as a process that requires both monetary and non-monetary inputs. The involvement of the poorest and neediest in O&M can be described as a vehicle to benefit from increased individual capacity and therefore as a constructive step in development." (Sohail et al. 2001). Community participation has to be seen as a critical component for the sustainability of a project. In the context of the decentralisation process that is going on in developing countries, many have recognised the importance to listen to the users and to hand over responsibilities to the community.

Participation (and its associated term 'empowerment') "are words that express the idea that it is possible for the poor to gain more influence over their lives." (Sohail et al. 2001). The definition of community participation ranges "from the provision of free community labour inputs in government projects, to autonomous self-reliant development." (Brikké 2000). Communities can become involved in a wide variety of ways in O&M or service provision. This can range from informal advisers to formally appointed micro-contractors with legally binding contracts. However, the degree to which communities participate is constrained by their ability and willingness to participate. Many have other priorities and in many cases there is in fact no sense of 'community' at all – they are just people living in the same area in an atmosphere of extreme stress (IWA 2006). It has been experienced that low-income communities, in general, consider that maintenance of service is the responsibility of either municipal councils or the concerned service provision institutions (Sohail et al. 2001). Participation in construction of facilities, however, has proven to create a sense of ownership and responsibility which subsequently encourages O&M activities.

Stakeholders in a community may have very different interests which vary with their social, economic, political, cultural and gender differences. It is important, therefore, to consider the whole range of community groups and interests, when encouraging participation.

Sohail (2001) distinguishes four levels of participation. The first two levels are prerequisites for the third and fourth.

- Information dissemination (one-way, top-down, flow of information)

- Consultation (two-way flow of information)
- Collaboration (shared control over decision-making)
- Empowerment (transfer of control over decisions and resources)

The level of empowerment refers to ‘community management’, although a clear definition for ‘community management’ does not exist (Brikké 2000). Community management, or the management of a service by its users or a user group, will be discussed later in chapter 4.5 (Management Options).

Community self-help

Community participation is not always encouraged by ‘outsiders’. Often community members organise services themselves, without external support and without any incentives other that their strong demand for an improved livelihood. Kyessi (2003) for example states for the city of Dar es Salaam, Tanzania: “Diminishing state resources coupled with inadequate urban management capacity and insufficiency of conventional approaches have rendered it impossible to provide basic infrastructure in urban areas in developing countries (…) As a result, communities, through self-help and local governance in their own neighbourhood associations, have organised to fill the gaps in infrastructure services left by the centralised institutions.” Kyessi (2003) furthermore states that among other things, community groups mobilise and organise fund-raising, mutual self-help and external technical assistance to provide water supply and sanitation (WSS), roads and drainage channels within the immediate area. This seems to be a trend in infrastructure improvement in poor neighbourhoods.

However, the idea that communities themselves can do a great deal to improve their conditions has to be viewed critically. Since the 1990s people-centred, bottom-up approaches to development have become increasingly popular. But apparently, the community concept is often used by the state or by donor agencies, rather than by the people themselves. In case a community initiative emerges, this can very well be a one-time event to accomplish identified shared needs, after which the organisation breaks up. It has to be kept in mind that communities are not homogenous social entities, but divided along class, ethnic, religious, age, and gender lines. Urban poor may be instrumental to improve overall living and working conditions, but they are also likely to reaffirm existing local power relations and patterns of exclusion (Post, Mwangi 2006). The ability of communities to express ideas and act may be severely constrained. The enabling environment for community self-help must be given – local authorities have to create a supportive atmosphere. Finally lacking financial (and managerial) capacities may hamper the ability of communities/individuals to take action. (see also chapter 4.7.3: Community Resources)

4.3.2 Social and Cultural Aspects

Sanitation strategies have to take account of the attitudes, assumptions and behaviour of the people that they target. The most theoretically sound sanitation system will provide no benefits if it is not used as intended, or worse - not used at all (Tayler et al. 2003).

In this context social and cultural aspects related to human excreta are of importance. The willingness of community members to carry out O&M tasks for a system that recycles excreta and greywater, depends strongly on the acceptance of the whole concept. Where poor farming households lack access to fertilisers, the use of excreta in agriculture is often well known and acceptable, but when civil servants working in cities are presented with the concept, these may have difficulty accepting it, often supported by their argument that the people who are expected to apply it would not accept it (WHO 2006). Beyond that, for example Mayumbelo (2006) states, that experience in Ethiopia, Zimbabwe and West Africa shows that the culture of the bureaucrats (and most engineers) is the most difficult hindrance (not the culture of the poor/users) to the philosophy of Ecosan. Subsequently socio-cultural aspects of both - the community and other stakeholders – play an important role.

When planning and operating a resource-oriented sanitation system, three cultural considerations must be addressed:

- **Psychological deterrents** associated with the handling human waste, which tend to be universal. The behavioural acts of elimination and treatment vary worldwide and motivations for use are diverse.
- **Gender issues**, which are both universal and local.
- **The influence of religion**, which varies regionally despite universal doctrines associated with a particular faith. [28]

"Cultural norms about waste treatment are universally similar to those on diet. Norms are both inherent and learned, and deeply rooted in psychology, gender and religion, which might explain why modifying a tradition of waste treatment is often as difficult as modifying a traditional diet. But to modify another's diet is one thing; to replace it is quite another."[29]

Psychological deterrents

"Human society has developed different socio-cultural responses to the use of untreated excreta" (WHO 2006). As the cultural beliefs in relation to excreta and wastewater use vary widely in different parts of the world, a thorough assessment of the local socio-cultural context is always necessary. Winblad and Simpson-Hérbert (2004) distinguish between 'faecophobic' and 'faecophilic' cultures.

In Africa, the Americas and Europe, use of fresh excreta is generally regarded with disaffection ('faecophobic'). Products fertilised with raw excreta are regarded as

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[28] Aus Warner, W. S. (no year): Cultural Aspects of Ecosan. PowerPoint-Presentation for myneworks.org, Ecosan - closing the loop in wastewater management and sanitation. In Heeb et al. (2006)

[29] ibid.

tainted, although large agricultural areas in many countries are fertilised with raw sewage, and the products find consumers. The views are less negative in relation to excreta-derived compost or wastewater sludge commonly used in agriculture, horticulture and land reclamation schemes. (WHO 2006) In Ethiopia for example, contact with human faeces is generally unacceptable. Even constructing 'a house for faeces' is low on the domestic agenda, especially among men (WSP-AF 2005).

Perceptions about urine are rarely documented, but most people entertain a more or less relaxed attitude towards it. Urine has traditionally been used to smear wounds or as an insecticide to kill banana weevils in East Africa (WHO 2006). After two years of demonstration of urine diverting toilets, users in seven West African countries use urine as a fertilising agent on different types of crops. “The appreciation of urine as a fertiliser was marked, e.g. in Anagbo in Bénin, by stored urine-filled jerry cans being stolen and then returned… empty!” (Kvarnström et al. 2006)

Use practices and perceptions of greywater have been little studied. Generally, the view of greywater disposal is relaxed, and little thought is devoted to its management.

Gender issues

Gender differences are substantial because women and men tend to play very different social and economic roles in society. It is important, therefore, to check that opportunities have been built into a project to encourage participation from a range of community groups and interests, in decision-making processes and to benefit from development (Sohail et al. 2001).

O&M tasks are often regarded as purely technical and men’s business. Opinions that women cannot perform maintenance and repair tasks are mostly based more on stereotyped gender concepts than on any real inability. Many publications even highlight that women may well make better maintenance and repair workers than men. The following reasons for that are given: the compatibility of preventive maintenance and user education with women’s gender-specific tasks[30]; the easier communication between female maintenance staff and female users; women’s greater sensitivity to social pressure from other women to do a good job; the importance of health aspects; the lower career orientation and labour mobility of women; and training of women in modern technology in recognition of their age-old skills in management of their domestic water systems. (Brikké, 2000)

Brikké (2000) furthermore proposes that a gender approach has to be taken towards O&M in order to analyse current gender divisions and to strive for an equitable balance between men and women of different ages and marital and socioeconomic status. He gives the following indicators:

[30] For example: “Women are mostly responsible for cleaning sanitation units; and often do so without any guidance from sanitation staff.” (Morna 2000)

- access to information
- amount of physical work
- division of contributions in time and cash
- degree of decision-making
- access to resources and benefits: water, training, jobs, income
- control over these resources and the benefits from them

The influence of religion

The influence of believe on daily life is sought to be greater in eastern cultures and developing countries than western industrialised countries (Heeb et al. 2006). For example in Islamic societies, direct contact with excreta is abhorred; according to Koran edict excreta are regarded as containing impurities. In contrast to raw faeces, dried and composted faecal material has a distinctly different appearance, similar to ordinary soil, and is more acceptable. It is odourless and has a soil-brown colour that reminds people of soil conditioner. Cultural avoidance of handling well processed composted faecal material is little reported (WHO 2006).

4.3.3 Tenure

Tenure is defined as "A bundle of rights which regulate access, use and ownership over land and other resources (for example water, trees and crops). Land tenure refers to arrangements and rights under which the holder uses or owns land." (Mulenga et al. 2004)

Insecure tenure and the prevalence of rental accommodation within a community are important. Both have profound implications for who makes decisions about investment in sanitation hardware and maintenance, who should be targeted by campaigns to stimulate demand and what routes there are for communication about behaviour change. In sub-Saharan Africa where subsidies are rare and households are expected to pay for domestic facilities, these distinctions can be crucial. (Schaub-Jones et al. 2006)

While unsecured land tenure does not appear to hinder development organisations from funding public latrines, entrepreneurs appear reluctant to invest in local infrastructure because the infrastructure may be demolished at any time. (Bongi, Morel 2005).

After Schaub-Jones et al. (2006) there is a broad inverse correlation between the prevalence of low-cost rental accommodation and sanitation coverage in the cases they visited[31]. There is generally greater investment in sanitation facilities where people have secure tenure or own their houses, and they are more likely to invest in improve-

[31] The authors reviewed on-site sanitation improvement initiatives in five 'very different' African cities (Dar es Salaam, Durban, Maputo, Maseru and Nairobi).

ments. This is not surprising as by definition, tenants do not own the property they live on; they pay rent and rely on the landlord to provide amenities like a latrine. They have little incentive to invest their own resources, are not often permitted to modify infrastructure or construct facilities without the approval of the landlord, and those who do invest might loose any compensation should they relocate or be evicted. Ecosan may be appropriate for tenants and landlords if investment costs can be kept low (shift from investment-based sanitation to fee-based sanitation). (Schaub-Jones et al. 2006)

4.3.4 Demand for Improved Sanitation

An uttermost important factor for sustainability is demand. Demand can is said to be an expression of the community's commitment, and a way to make them responsible for their choices and future tasks (Brikké 2000). Sanitation systems that do not meet demand have problems of under use, poor maintenance and poor cost recovery (Deverill et al. 2002).

According to Brikké and Bredero (2003), the provision of water-supply and sanitation improvements can be characterised as either demand-driven or resource-driven. With a resource-driven approach, the project is implemented with minimal involvement of the community. Problems with this approach include lack of community acceptance and poorly functioning improvements that are underused. O&M costs can also be a concern if the technology was introduced without involving all interested parties and without a proper analysis of local needs and conditions. With a demand-driven project, problems and needs are identified with the full participation of the communities. The advantages of such an approach are that the community is motivated to participate in the planning, construction and O&M phases. It is more likely that a demand-driven approach will better foster a sense of ownership and responsibility.

Thus the knowledge of what drives peoples demand for sanitation is an important factor. One might be tempted to suppose that peoples demand for improved sanitation is based on health reasons. Often demand is driven by other considerations. Asked to prioritise reasons for satisfaction with their new latrines, rural householders in the Philippines and Benin said the following:

Table 8: Why do people want sanitation?

Rank	Philippines	Benin
1	Lack of smell and flies	Avoid discomforts of the bush
2	Cleaner surroundings	Gain prestige from visitors
3	Privacy	Avoid dangers at night
4	Less embarrassment when friends visit	Avoid snakes
5	Less gastrointestinal diseases	Reduce flies in compound

Source: (WSP August 2004)

Health considerations are at the bottom of the Philippines list and even further below (13th) on the list of Benin. Often sanitation projects stressed the health dimension, whereas a marketing approach (for instance through social marketing approaches - these look to combine business marketing principles with socially desirable goods and services) would have been more successful (WSP August 2004). For Ecosan the case is interesting, too. In the past, only few choose to build an Ecosan toilet for supporting agriculture. For example the majority of households with Ecosan toilets in Uganda state that they built them primarily as a sanitation facility (WSP-AF 2005).

Convenient use and operation have proven to be of significant importance for users of sanitation facilities, including the level of comfort, privacy and security. The cost to construct and maintain installations is another important consideration. Ecosan toilets can be built at the same or even at lower prices than conventional VIP latrines and convenience is high if the design is sophisticated and adapted to the users demand.

However, the concrete expression of demand varies with the locality and the implementing organisation. Demand can be manifested in the form of an initial contribution in cash or in kind to the capital cost, or in form of a written solicitation from a community group (Brikké 2000).

4.3.5 Information, Education and Support Activities

Information, education and support are a prerequisite for sustainability. For O&M, already during planning and design, division of responsibilities and definition of tasks have to be considered and require furthermore the agreement between parties concerned. Awareness raising, motivation, training and incentives are preconditions for creating the conditions in which responsibilities can be implemented (IRC 1997).

Sanitation interventions must consider the way in which institutions operate and the assumptions that underlie existing practices. One normally thinks of institutions in terms of their structures and systems, but their performance is also strongly influenced by the way in which the people within them routinely think. For instance many people in government institutions think only in terms of official service provision, ignoring the contribution to sanitation made by ‘informal’ providers. Strategies to improve sanitation will need to involve efforts to foster new ways of thinking and acting within the organisations that provide sanitation services. (Tayler et al. 2003)

In many areas of East Africa there is shortage of qualified manpower, particularly in the professional and technician levels (UNEP 2002), but also managerial skills are missing on the local level. All stakeholders in O&M management have to be trained extensively. For community management, Sohail et al. (2001) say that NGOs and CBOs may have a role in building the financial management skills for required in fundraising activities and managing finances. Organisational skills are also needed to mobilise the community and manage conflict. NGOs and CBOs often are key in instituting participatory methodologies for planning and evaluation, and assisting communities to deal with politicians and local government. Thus, agencies need to have all these skills in order to train the community if skill gaps exist, but also need skills in social organisation, communication, developing programmes in hygiene education training, monitoring and follow up/evaluation.

The ROSA project tackles knowledge and behaviour related constraints to the sustainability of the implementation. Information, education and communication (IEC) material will be produced for distribution among the stakeholders. For O&M, the IEC campaign ideally tackles the socio-cultural hindrances, stimulates demand and willingness to participate in O&M, stimulates people to change their behaviour if necessary and trains users, staff and administrators how to operate and maintain the whole system.

For the implementation of urban Ecosan systems a public education campaign needs to be designed and implemented before construction begins. Demonstration units should be built within neighbourhoods so that households know what is coming[32]. Key- or model-families are a good way to make visitors familiar with the system and its requirements. All sorts of civil institutions could be targeted such as men's and women's organisations, schools and religious institutions. If a municipal management is implemented, the municipality might have to set up new types of urban services and training for its workers, and this might need a period of research or trials. The key local authorities and field staff must be properly trained in O&M and may also need training in community empowerment methods (Winblad, Simpson-Hérbert 2004).

Particularly for Ecosan IEC campaigns are important because facilities used in this approach need a big deal of user care and cultural hindrances in handling faeces are always prevalent. A range of IEC tools exists and according to Kvarnström et al. (2006), there are different successful examples of how to raise awareness around urine diversion, for example. If on-site treatment and reuse of the fractions can happen, household members must know how to operate and maintain the eco-san devices in their homes. For that, a high degree of motivation and awareness raising as well as a steady and efficient external support (experienced man power and financial resources) are needed on site, at least for a certain initial period of time (Werner et al. 2005).

"Because of high levels of illiteracy, conventional training methods may be ineffective. Many local projects are not achieving the expected results because of a failure to provide effective education." (WHO 2000b). Illiteracy is still common in many parts of Eastern Africa. The Illiteracy rate of the population older than 15 years is estimated to be more than 66% in Uganda, for example (Hammer 2002). This implies that IEC materials have to be designed that way that also the illiterate people can understand and use them.

Children should be educated already in school about hygiene and sanitation practices. They often learn more quickly and enthusiastically than adults and thus might be the ones who stimulate their family at home to change their behaviour.

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32 In the ROSA project this is happens by building and operating a demonstration system in the peri-urban area of each city.

Behavioural change

Changes in behaviour are most important when it comes to the improvement of health related habits. Hand washing after defecation or wearing protective clothes when handling faecal matter are just some of the aims. It has to be kept in mind that, if changes are minor and socially unimportant, altering established practices are likely to meet with social acceptance. But any attempts to alter a social preference are likely to fail (WHO 2006).

Hygiene improvement is one aim of behavioural change approaches. In resource-oriented sanitation the additional aim of improving people's behaviour related to the collection, treatment, transport and reuse of excreta, greywater and solid waste has to be considered. To simplify treatment and improve the quality of the resources recovered, separate collection and treatment of different waste streams are commonly practised in resource-oriented sanitation. It generally requires a change in behaviour among the users. For example if households are willing to segregate their waste at source it saves a tremendous amount of time and costs for a composting scheme[33] (Rothenberger et al. 2006).

It has to be kept in mind, that when learning, people remember 20% of what they hear, 40% of what they hear and see, and 80% of what they discover for themselves. This calls for a change in the way teaching is carried out—from a didactic to a more participatory and growth-centred education. Four major factors stimulate people to change their behaviour (Brikké 2000):

- facilitation (convenience, making life easier);
- practical understanding;
- influence of others;
- capacity to change.

O&M manuals

In community managed projects there is seldom a formalised approach to O&M, like O&M manuals covering tools, works, description of activities, items to replace, recording of malfunctioning, repairs and replacement. This is particularly surprising where communities have been involved in the construction of systems, since such involvement is aimed to develop a strong sense of ownership and responsibilities for systems and thus promote O&M (Sohail et al. 2001).

If communities are responsible for the services they need information and training on follow-up and maintenance. Communities benefit from manuals to assist them in supervising O&M activities. For example, in a project in Zambia a manual was designed, it "uses cartoons and simple instructions to provide communities with information (…) it also includes chapters on rehabilitation, roads, wells, and pit latrines." (de Silva 2000).

Deverill et al. (2002) recommend that the local management organisation is left with a practical manual detailing its tasks, how to carry them out, and who to contact should a problem arise. Such a manual could also include details of the technical and financial tasks that the management organisation is responsible for. In any case it is highly recommended that those implementing a project produce a detailed O&M manual, handing it over to the responsible stakeholder/ organisation once implementation has been completed. Ideally, the manual would be developed and used during implementation as a training aid, as "(…) all responsibilities of a management organisation should be tested and practised during implementation." (Deverill et al. 2002)

Key Issues

Communities can become involved in a wide variety of ways and their participation in O&M is a critical factor for success. They can not be seen as homogenous social groups, they are divided along class, ethnic, religious, age and gender lines. Often individual's interests are the driver for action rather than a sense of community, thus, effective participation is only possible if individuals see a personal benefit. Community self-help initiatives are common but efforts are often constrained by a lack of financial and management capacity as well as by non-supportive authorities. Demand for improved sanitation has to be seen as very important - it impacts on the individual's perception of the service and his/ her willingness to pay and/or to participate in O&M. Demand is principally driven by convenience and social status rather than health issues. Social and cultural aspects related to sanitation and especially to excreta reuse are furthermore decisive. The tenure/ tenancy status of a community impacts on the willingness to invest in hardware and maintenance. Participation in construction can create a sense of ownership and responsibility. Information, education and support activities are a prerequisite for sustainability and should take place before, during and after the implementation stage. Activities should aim at (public and private) institutions and individuals. NGOs and CBOs can be very helpful partners for awareness creation and in training O&M, management and financial issues. Information and education can help to overcome psychological deterrents and stimulate demand. Formalised approaches to O&M, together with manuals, assist individuals, groups and institutions in effective O&M.

[33] Moreover, it increases the quality of both biodegradable waste and recyclables.

4.4 Technology

4.4.1 Selection of Technology

The selection of a particular technology can have far-reaching consequences for the sustainability of the services. Often technical criteria and initial investments are emphasised when choosing such technologies. Brikké and Bredero (2003) propose that an O&M component be added to the selection process. Furthermore, they outline two basic principles: (i) that communities need to be involved in selecting technologies from the start of the process, and (ii) that planners should adopt a demand-driven approach. Adopting these principles an option review is recommended at the planning stage to provide people with an appropriate and environmentally sustainable choice of options. According to Deverill et al. (2002) this is not simply a question of 'knowing the technology'. Communities and local authorities and/or the private sector should be made aware of the financial implications of operating, maintaining, managing, rehabilitating and replacing a given technology. Hence, during technology choice priority should not necessarily be given to systematically minimising investment costs, but also in analysing O&M costs that communities can afford and are willing to pay. (Cardone, Fonseca 2003)

Winblad (2004) says: “In practice, pilot peri-urban sanitation programmes involving free or highly subsidised demonstration models are likely to fail in the long run when false expectations have been raised regarding the cost of the system.”

The community should select the technology, with support from the agency. This will contribute to the sustainability of the technology and increase the number of community members who will use it. According to Brikké and Bredero (2003), the selection process should include at least the following steps:

I. **Request improved services**
The first step is for a community to request improved services.

II. **Carry out a participatory assessment**
Data should be collected on all the factors listed in Table 9.

III. **Analyse data**

IV. **Hold discussions with the community**
Discussions should be held with the community about sanitation options, and include discussions about the technical, environmental, financial and hygiene implications of each option.

V. **Select the technology**
The community should select the technology, with support from the agency. This will contribute to the sustainability of the technology and increase the number of community members who will use it.

Table 9: Factors that influence the selection of community sanitation technology

Factors of general relevance	Factors specifically relevant to O&M
1. Technical factors	
– design preference (substructure, floor slab, squatting or raised seat, superstructure); – technical standards and expected lifetime of the technology; – availability of construction materials; – cost of construction.	– O&M requirements; – ease of access; – use of decomposed waste; – emptying technique.
2. Environmental factors	
– soil texture, stability, permeability, fertility; – groundwater level; – control of environmental pollution; – availability of water; – possibility of flooding;	– O&M implications for environmental protection; – protection against groundwater contamination; – protection from flooding.
3. Institutional factors	
– existing national/local strategies; – roles and responsibilities of actors implied; – training capacity; – availability of subsidies and loans; – availability of masons, carpenters, plumbers, sanitary workers, pit-emptiers and pit-diggers.	– emptying services (municipal/private); sewerage maintenance capacity; – potential involvement of the private sector; national budget allocations for sanitation; training and awareness education; – monitoring.
4. Community factors	
– **sociocultural aspects:** taboos, traditional habits, religious rules and regulations, cleansing material, preferred posture, attitude to human faeces, gender-specific requirements; – **motivational aspects:** convenience, comfort, accessibility, privacy, status and prestige, health, environmental cleanliness, ownership, demand for recyclates; – **discouraging factors:** darkness, fear of falling in the hole, or of the pit collapsing, or of being seen from outside, smells; insect nuisance, lack of demand for recyclates; – **social organisation factors:** role of traditional leadership, religious leaders, schoolteachers, community-based health workers; – **other factors:** population densities, limited space for latrines, presence of communal latrines.	– O&M costs; – O&M training and awareness for sanitation; health awareness and perception of benefits; – presence of environmental sanitation committee; – women's groups; – social mobilisation on hygiene and sanitation behaviour.

Adapted from: (Brikké, Bredero 2003)

<u>Sustainability Criteria</u>

In order to select the most sustainable sanitation option, one furthermore has to consider sustainability criteria. Based on the approach presented by Kvarnström and Petersens (2004), Münch and Mayumbelo (2007) applied the following four selection criteria, which shall be adopted here. The technology:

- should not pollute groundwater;
- should not require water for transporting waste (poor water supply levels in peri-urban areas);
- should sanitise the waste to destroy pathogens to protect public health; and
- should have low capital and O&M costs to be financially sustainable.

O&M Requirements

Users and operators should be made aware of the O&M requirements of all presented options. According to Sohail et al. (2001), the identification of O&M technical requirements involves:

- Components of the scheme
- Description of O&M activities
- Description of O&M requirements
- Identification of tasks (monitoring, preventative maintenance, minor repairs and major repairs)

Brikké and Bredero (2003) provide information on O&M activities required for a broad selection of sanitation system components. The description of each technology includes: the O&M activities required, and their frequency; the human resource needs; and the materials, spare parts, tools and equipment needed. Options like urine-separating systems and bio-digester technologies are not included. Only toilet facilities, collection and transportation are covered – treatment technologies are left out.

In Appendix C, O&M of some on-site technologies is described.

4.4.2 Spare Parts[34]

The lack of spare parts may be a major constraint in the sustainability of sanitation services and can even lead to the services being abandoned (see chapter 5: Case Study). Many donors are only involved in the construction phase of the project and make no provision for continuing the supply of spare parts after handing over the project to the community[35]. Some donors have attempted to overcome the problem by supplying a stock of spares at the time of installation. But this is only a short-term remedy, because the absence of a supply system and the lack of foreign exchange means that stocks do not get replenished.

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[34] Source: (Brikké, Bredero 2003); if not marked in another way.

[35] A lack of spare parts can also result from policies pursued by the donors, such as when hardware has to be purchased from the donor countries

Availability of spare parts should be one of the main factors that determine the suitability of a particular technology. Before selecting a technology, the mechanism for supplying spare parts must be investigated, established and assured. The community will need to know the cost of running their sanitation systems, and this will be determined partly by the demand for spare parts. Estimates may be based on previous experience, or on guidance from the manufacturers. However, care must be exercised when using these figures for spare parts, since the need for spares will vary according to local circumstances. The extent of use, the care with which the equipment is used, and the effectiveness of preventive maintenance will all have an impact.

Spare parts can be divided into three categories:

- frequently needed spare parts, for which the accessibility should be as close as possible to the community (shop, mechanic);
- occasionally needed spare parts (every six months or every year), for which accessibility can be at a nearby major centre;
- major rehabilitation or replacement spare parts, for which accessibility can be at the local or regional level, or at the state capital.

Standardisation issues

Several countries have chosen to standardise the choice of technology; this choice has positive as well as negative aspects (see Table 10 on the next page). Supply of spare parts can be improved if the parts are manufactured within the country of use. The equipment should be designed so that the parts that wear out are simple to manufacture from readily-available materials. Manufacturers can be encouraged to produce the equipment locally by mobilising local entrepreneurs.

Table 10: Pros and cons of standardising technology

For standardisation	Against standardisation
– simplifies O&M by limiting the range of spare parts and expertise needed – common use of the same item of equipment encourages agencies and shopkeepers to store and supply spare parts, because there is a ‘guaranteed demand’; – standardisation avoids the proliferation of brands and technologies, which would make it easier to stock and supply spare parts; – the prices and market for spare parts can be more easily determined; – users become familiar with one type of technology; – personnel training can be standardised.	– the chosen technology does not fully respond to the needs and preferences of users; – the market is closed to new, innovative and cheaper technologies; – there is little incentive for the private and research sectors to become involved; – standardisation limits price competition between different brands and impedes optimisation; – limiting technology choice may conflict with donor policies.

Sources: (Brikké, Bredero 2003), (Sohail et al. 2001)

Key Issues

Selection of technology is a process that has to be carefully planned. The community has to be involved and given the possibility to choose their preferred option. However, this selection should be based on informed choice and happen with support from the implementing agency. A participatory assessment will highlight the community's preferences, motivational and discouraging factors in regard to different technologies. The impacts of different technologies on O&M must be made clear to everybody. Sustainability criteria have to be defined to ensure environmental, institutional and technical sustainability. Basically, the demand has to be met and at the same time sustainability has to be ensured. An important technical factor for sustainability is the availability of spare-parts. In developing countries, the procurement of unusual spare parts can be a great challenge. Thus, before selecting a technology, a supply system for spare parts must be established and assured. Simple technologies with easy to make spare parts should be preferred. Standardisation of technology has several advantages and disadvantages - however, for innovative low-cost technologies given standards are often inadequate and may even hamper their implementation. In Appendix C O&M requirements and roles and responsibilities for several on-site sanitation technologies are given.

4.5 Management Options

In most cases where the provision of sanitation services has failed, the root causes have been poor management, lack of planning and failure to generate revenue sufficient to operate and maintain systems. Effective and efficient management is the key to ensure sustainable O&M. This chapter deals with management options for resource-oriented sanitation systems.

4.5.1 Background Information

Issues affecting the choice of management models for O&M

The choice of an O&M management model for sanitation systems is influenced by several key issues. Key issues given by Brikké (2000) were adapted for the peri-urban context and issues, that are likely to be of significance for resource-oriented sanitation approaches, were added:

- **Capacity of community organisations**
- **Key community skills**

  A community assessment is a useful tool to assess the local capacity for community management (see chapter 4.5.3). Among the key community skills that must be considered in assessing local management capacities are leadership, accounting, and mechanical skills. Training is one way of upgrading community skills. There are limits to training adults with a low level of literacy, but for most areas of community need, instruction within these limits can achieve adequate results.

- **Health education and community participation**

  In addition to technical and management training, the community's understanding of health, hygiene and community participation is important (see chapter 4.3). This understanding may vary considerably from region to region. Female literacy is particularly important, since women are the key implementers of health practices.

- **Gender-balanced development**

  See chapter 4.3.2: Social and Cultural Aspects

- **Complexity of technology**

  See chapter 4.4.1: Selection of Technology

- **Availability of spare parts**

  See chapter 4.4.2: Spare Parts

- **Standardisation and local manufacture of equipment**

  See chapter 4.4.2: Spare Parts

- **Requirements shared with other sectors**

Procurement problems often can be eased by considering the requirements that the sanitation sector shares with other sectors. The housing sector, for example, uses toilets, pipes, and building materials. Waste services, use containers, vehicles and treatment processes. The market for equipment in one sector can influence decisions in another sector.

- **Capacity of the private sector**

  see chapter 4.5.5: Private Sector Management

- **Cost recovery mechanisms**

  See chapter 4.6: Cost Recovery

- **Ability and willingness to pay**

  See chapter 4.6.3: Capacity and Willingness to Pay

- **National and regional economies**

  High rates of inflation, cost of living, and unemployment have a significant effect on O&M management. High inflation requires careful attention to budget planning. Fuel prices are critical for sanitation projects that use motorised vehicles (e.g. vacuum trucks, tractors). Unemployment can create a large labour pool for labour-intensive tasks such as the operation of composting facilities. Some communities may carry out construction and O&M work without remuneration as their contribution to the project.

- **Logistics and transportation**

  Long distances to treatment sites or reuse areas, and bad roads will add to project costs and increase the uncertainties in planning. Long distances to treatment plants can result in illegal dumping of FS. Narrow lanes may not be accessible for conventional emptying vehicles. The use and siting of transfer points is an important factor to consider. Communities could be responsible for the transport to decentralised transfer points or treatment stations and the municipality or private service providers for long distance transports. These matters will require special attention in the logistics of collection, transport, treatment and reuse.

- **Government leadership**

  The strength of government leadership is an important factor in selecting a management model. However, in the decentralisation context, government’s role is changing from a supplier of services to that of sector coordinator and facilitator.

- **Strength of government agencies and staff**

  Institutional effectiveness is a critical factor and is influenced particularly by the organisational framework and the quality of the staff. The organisational framework should encompass all the components of the sanitation sector from planning and design to O&M, with support for programmes of health education, community participation and (peri-urban /urban) agriculture.

- **Policies and legislation**

  See chapter 4.2: The Institutional- and Legal Framework

- **Communication and information sharing**

  Objectives can be met only if adequate information is available at all levels from the communities to the central government. All stakeholders should be fully aware of policies, legislation, decrees, administrative decisions, and any other pertinent matters. While the lack of technological hardware sometimes impedes communication with distant points, more often it is a lack of will that is the cause. Frequent visits by project agents to the communities are an important means of communication, as are audiovisual aids such as posters, bulletins, radio-shows and videos.

- **Social and cultural factors related to the reuse of human excreta**

  See chapter 4.3.2: Social and Cultural Aspects.

- **Demand for recyclates**

  A strong demand for recyclates can lead to the strong involvement of the private sector when profit chances are given. If demand is weak and can hardly be stimulated, the municipality might also use the recyclates in parks or other public green areas. If urban/ peri-urban agriculture is prevalent, excreta can ideally be recycled in the household zone. This would shift the management requirements towards support activities and monitoring.

Overview - Management models

In the context of decentralised sanitation, decentralised management may provide opportunities for O&M tasks to be carried out correctly by local stakeholders, who have a greater incentive to ensure that facilities continue to perform as intended (because they are responsible for O&M of facilities that impact directly on their convenience, health etc.). However, there are few experiences with local management models for sanitation (Brocklehurst 2004). Local management for decentralised sanitation is only a complete solution, if material cycles can be closed on the local level. In larger towns a town-wide management or control system should be installed for the overall coordination of the systems. Decentralised management solutions have to be monitored – especially health issues and compliance with treatment targets, as a public concern, must be controlled by higher level institutions.

The cooperation of various different stakeholders and the variety of possible organisational and financial structures should be seriously taken into account during the conception of management systems. Management options basically consist in a blend of ownership and responsibilities between the public sector, users (or user associations) and the private sector. This reflects the basic goods which drive stakeholder participation, identified some chapters before (public good, private good and provider's good). In the following table (Table 11) various management options are presented:

Table 11: Summary of various management options

Management Options	Main Characteristics
Direct municipal management	
Direct administration	Administration by the municipal service or department, with no autonomous budget. Controlled by the mayor.
Autonomous administration	Administration by the municipal service or department, with autonomous budget and separate services.
Semi-direct municipal management	
Inter-municipal administration	Administration agreements between several municipalities, with a coordination unit controlled by the municipalities, for managing the system
Direct or autonomous administration with some activities delegated to other firms	Administration by the municipal service, with activities delegated under a contractual service agreement to other firms for a specific task, and a limited period of time.
Delegated management	
Management contract to a firm or individual	While the municipality remains responsible for the service in investment and tariff setting, it delegates their management to a firm or an individual, under a remuneration contract.
Special management contract to a firm or an individual	Same as management contract described above, but with a remuneration based on a fixed agreement with the municipality and a percentage of the collected tariffs.
Leasing/renting contractual arrangements with a firm	The municipality establishes a contract with a firm, which will not be responsible for the investments, but only for the O&M of the system, whose remuneration comes through collected tariffs.
Public administration (cooperative association)	Distinct legal status, and financial autonomy. Controlled by the Assembly of Associates (where the municipality is a member among others), with the authorisation of the Municipal Council.
Concession to community associations	Associations created by a General Assembly of users, with the authorization of the Municipal Council. It manages and operates the system.
Concession to a private firm or society	Under a contractual agreement between the firm and the Municipal Council, the firm will fully manage, operate and maintain the system, with complete financial autonomy. The firm will invest with its own resources, at its own risks, but the municipality must approve them.
Private management	
BOOT contractual agreement (Build-Own-Operate-Transfer). Also possible: BOT (Build-Operate-Transfer); BOO (Build-Own-Operate); Inverse BOOT.	Under a contractual agreement, a private firm is totally responsible for the construction, operation and management of a system, but will transfer it to the municipality at the end of the contract, which is usually long term. For the inverse BOOT, the public authority builds, but the system becomes private at the end of the contract.
Private management with public/private capital	Private company whose shares are public and private; some control is kept at the shareholders' assembly.
Private management	Private company owns the system and is totally responsible.

Source: (Brikké 2000)

4.5.2 Direct Municipal Management

In this management option, the municipality is directly responsible for the administration of the sanitation service, through a department or unit which has been created for that purpose. Brikké (2000) states that several conditions are applicable if the municipality opts for direct management:

- direct municipal management will be possible only if the municipality has made a public call for firms to operate, manage and maintain the system, and if no one has proposed its services;
- direct municipal management will be possible even if a private or public firm is available, only after a study has shown that the operating cost of direct municipal management will be lower than that of the private firm, and the quality of the service to the users will be higher.

Limitations of this approach relate to both the capacity and performance of the institution and the extent of the service coverage, particularly when poor urban settlements are covered (WHO 2000a). The current trend goes away from municipal management towards the involvement of the private sector and community organisations.

However, public authorities still have an important role to play in decentralised solutions implemented on a larger scale and managed by different stakeholders. Public authorities cannot be released form the responsibilities to ensure public health. For that, these authorities have to develop (i) legislation to ensure a hygienic and healthy environment (ii) public control and advisory support to the users and other stakeholders on how to construct, operate and manage resource-oriented systems in a hygienic and environmental friendly way. As tools, incentives and sanctions exerted by local governments can be vital assets in promoting and managing resource-oriented systems (Knapp et al. 2001). Furthermore, public authorities will have a commitment to coordinate stakeholder activities.

4.5.3 Community Management

Community management has different connotations in the literature. The responsibilities, the community is assigned to, vary widely for this concept. However it can be said that community management has increasingly been seen as a fundamental option for sustainable development (Brikké 2000). The community-managed approach involves the residents and community groups who undertake to manage aspects of neighbourhood work; this could involve people doing things themselves and/or hiring labour for routine and skilled tasks. The community management approach is more often associated with rural areas than with urban areas. Constraints in urban areas are around the issues of low community sense among urban / peri-urban dwellers and the tenancy status in low-income settlements. It has to be kept in mind that (WHO 2000a):

- the activities have to reflect both the willingness to participate and the capacity of the residents; and

- major repairs require a degree of technical and contractual input, and therefore risk, which the residents may not be prepared to assume.

If the ownership of certain facilities is not with the managing organisation/ individual, voluntary O&M is critical. An analysis of public latrines in the informal settlement of Kibera, Nairobi for example, shows that voluntary maintenance does not deliver an effective and efficient service. “On the contrary, commercial management leads to a quality service and well-maintained facilities, irrespective of whether the block is owned by a private operator or a CBO.” (Bongi, Morel 2005).

Sohail et al. (2001) however found that some urban communities had succeeded in (i) analysing their own settlements and infrastructure needs, (ii) planning, locating and playing a part in the construction (iii) partly paying for infrastructure; and (iv) organising strategies for paying for and organising the on-going work in O&M. The authors concludes that the long-term community management of services depends on the placement of urban services in a development context, which may include:

- A sense of ownership of the system and a felt need (a service that people want and are willing and able to pay for)
- Participation of users and agencies in the process, and the capacity building of both (demystify expertise, strengthening/development of institutions, different methods of management, creation of an enabling environment/supportive attitudes)
- Support services (institutional reform/supportive policy frameworks and financial, technical, social and customer services)

The community management option furthermore requires a clear understanding of the roles and responsibilities, such as (i) how to interface with formal institutions operating in the city in order to cover the eventualities of major works; and (ii) the definition of minor as opposed to major O&M tasks and the responsibility for action (WHO 2000a).

Deverill et al. (2002) extend the principle of user choice from technology selection to selection of management and contribution systems. They see the following issues arise:

- Potential management and contribution options need to be identified before they can be developed.
- The introduction of multiple service levels and associated contribution systems will add significantly to the responsibilities for local management. This should be reflected in capacity building and training.
- Local management systems cannot operate in total isolation but inevitably need a degree of support from the responsible authority. The provision of higher service levels will increase this requirement.
- Managers and their staff need incentives. An over reliance on volunteers has led to some local management organisations being short lived. In many countries this factor has contributed to the under achievement of water and sanitation projects.

- Management can be significantly strengthened by legal recognition. It is often possible to register a water and sanitation committee with local government. A legitimate committee is also more likely to receive technical and managerial support from local government. Local disputes can be avoided by formalising the ownership of facilities.
- Registered committees may be responsible to a local authority, potentially improving their transparency and accountability. For example, there could be a requirement to submit books to local government for annual audit.
- A project can only have a single management system, reinforcing the need for an appropriate mechanism for collective decision-making. Checks may be required to prevent a powerful elite undermining or dominating management decisions. Traditional systems may be used or adapted if they are transparent, representative and accountable.
- Options based on community management but which involve contracting out certain roles or services to the private sector are seldom encountered but could fill an important role.
- Often technical issues are given priority over management and contribution systems. Someone in the project team must be made responsible for facilitating the identification, development and selection of management and contribution options.

Availability of skills

Before any tasks and responsibilities can be handed over to the community a community assessment should be used to assess local capacity for community management. The assessment should be a key to developing mechanisms of support and capacity-building. According to de Silva (2000) the institutional capacity of communities can be assessed by examining the following:

- **Organisational capacity of the community**. Are there formal or informal community organisations? Is there homogeneity with the benefiting group? Is interaction and joint action possible? Are existing groups representative of community interests?
- **Technical skills**. What do they produce? How do they procure goods or works? Is there surplus labour?
- **Financial and accounting skills**. Are there mechanisms for ensuring accountability within the community? If not, can they be designed? Who will monitor the proper use of funds?
- **Role of intermediaries**. Are there intermediaries operating within the community? Do such intermediaries have a close relationship with the community?
- **Cost-benefit analysis**. What are the costs of involving communities? Training costs? What are the additional risks? What are the benefits of involving communi-

ties? Increased sustainability? Will such involvement result in more effective use, O&M of facility? Is cost-sharing possible?

- **Beneficiary contribution**. Can communities contribute? If so, how?

Concession to community associations

Brikké (2000) names this management model if communities can already count on existing associations (e.g. CBOs), which sometimes have been organised in an informal way. It is important in this case that these associations are organised in a formal way, and obtain legal status. These CBOs will be established as non-profit-making associations with the aim of providing a public service, which could give access not only to community resources but also to resources coming from the municipality or the central government. The mayor can be a member of the association but has to promote community participation and facilitate access to funding. The community association is organised in the following way:

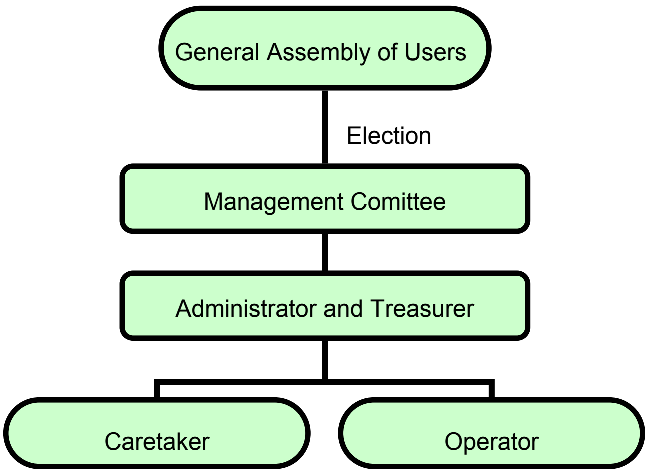

Figure 20: Organisation of the community organisation (Brikké 2000)

According to Brikké (Brikké 2000), the General Assembly adopts decisions and elects the members of the Management Committee of the association. The Management Committee is composed of a president, a vice-president, a Treasurer or Administrator, a secretary, representatives from the users, a representative from the local administration (if decided by the General Assembly, and if the local conditions allow it). The General Assembly has the responsibility to supervise and control all managerial, technical and financial aspects of the service. The caretaker and operator are responsible for the operation, maintenance and conservation of the whole system; they participate in tariff collection as well. The association has to be created by a decision of the General Assembly which passes an act constituting the Committee. The General Assembly must study and approve the rules and regulations for the functioning of the organisation. The constituting act and the rules, together with a written application, are registered with the chamber of commerce. The creation of such an association will be authorised through an official document of the municipal council.

4.5.4 Household Management

"Household-centred approaches are possible to some extent in both rural and urban areas, and suffer few of the problems and drawbacks of centralised and community-based O&M management." (WHO 2000a). In household-managed systems, the responsibility for O&M of privately owned on-plot facilities rests with the owner or plot-holder. In this respect, on-plot facilities have several big advantages, such as:

- a powerful incentive for householders (they have invested in the system and will benefit from it) to keep their facilities in optimum working order;
- repairs are carried out by the householders;
- householders finance all the O&M costs;
- clear opportunities exist in urban areas for small private-sector local contractors;

However, problems can arise for the wider community if household activities have an adverse impact on the local environment, e.g. malfunctioning latrines or tanks discharging untreated sewage off the plot. From the user's perspective, environmental health gains from sanitation investments are driven to a very large extent by the impact that they have at the household level that is in and around the home. This is where most people, and especially children, spend most time, and are most vulnerable to contamination. That is why in denser urban and peri-urban areas the first priority for most families is a clean and pleasant household followed by a better environment in the street and community. There is rarely much concern for the wider environment of the city or downstream areas. Where competent utilities are operating and there is a history of environmental management, this simply translates into household willingness to pay for the utility to 'take care' of downstream issues. Where there is no 'trusted' or competent service provider this translates into households or neighbourhoods discharging wastes downstream to contaminate the next quarter of the city or town (IWA 2006). As said before, household and decentralised management solutions are desirable, as they link O&M responsibilities with benefits accrued on the certain levels. However, there must be an organisation / management system on the higher level to control household and decentralised management – to ensure public-health and also performance of O&M.

4.5.5 Private Sector Management

The past decade has seen an increase in the role of the private sector in service provision, especially in large urban areas. Although the best known examples have been in assigning concession or management contracts for providing services in large cities, there have been a few examples of such contracts in small towns. Service contracts are the most common form of private-sector participation, but they are usually quite limited in scope. Such contractors are typically rather small and take on minimal commercial risk. Although small contractors have generally focused more on water supply, they also can play a role in household sanitation improvements (Rosensweig, Perez 2002).

According to UNEP (2002), the following basic policy principles should guide private sector participation to ensure optimum benefit to the public as well as the private sector company.

- Performance of the service providers must be monitored;
- The engagement of private sector should provide for technology transfer and capacity building;
- The service providers must be accountable to the people they serve;
- Provision of infrastructure must be done in a sustainable manner; and
- Opportunity should be given to all competent contractors to bid for the contract.

However, bidding for public works contracts has its drawbacks. The formal bidding process takes time and requires paperwork, and the selection process is not always transparent (Collignon, Vézina 2000).

Formal and informal private sector

At first a distinction between the formal and informal sector has to be made. The dividing line between the formal private sector of a country and its informal sector is, however, difficult to determine. Although there is still no generally accepted definition of the term `informal sector, ' in this thesis the term `informal sector' refers to small scale units which typically:

- Consist largely of independent, self-employed producers
- Operate with very little capital, or none at all
- Utilise a low level of technology and skills
- Therefore operate at a low level of productivity
- Generally provide rather low and irregular incomes
- Are for the most part unregistered and unrecorded in official statistics
- Have little or no access to organised markets, to credit institutions, to formal education or training institutions
- Are not recognised, supported or regulated by the government
- Are generally unorganised and in most cases beyond the scope of action of trade unions and employers' organisations (Rehan et al. 1996)

Although these characteristics are generally associated with the informal sector, in practice this sector manifests itself in many different ways. Bockelmann and Samol (2005) distinguish between large private providers and small-scale enterprises, which may be equal to the distinction between formal and informal sector. According to them, large private providers (respectively 'formal sector providers') of sanitation services are usually highly competent and often have international experience. In developing countries, their service quality is typically much better than that of public sector providers. However, they can also face serious problems in urban poor settlements when they fail to win the trust of their customers. Moreover, the technical solutions applied by large operators are not always appropriate for urban poor settlements. Large formal sector enterprises generally refrain from the risks of involvement in urban poor settlements with customers they perceive as having a low capacity and willingness to pay. They therefore only deliver service to poor areas when their financial risk is limited by guarantees or financial compensation from their public sector employers.

<u>The role of private small scale service providers in sanitation in African cities</u>

In African cities the private-sector already plays a major role. Most households and virtually all poor households deal with their own waste by building their own latrines or septic tanks or hiring others to do it. Since the public sector is generally not involved in this area, private providers dominate the market. They offer services tailored to customers' needs and incomes, for the tasks that households choose not to carry out themselves: masons who build latrines, manual latrine pit cleaners, suction truck operators for septic tanks, and manual or mechanised drain and latrine ditch cleaning services (Collignon, Vézina 2000). Furthermore construction and operation of public toilet facilities, which private small-scale enterprises often undertake, is another domain of the private sector. Figure 21 shows the average monthly revenue of private small scale service providers (PSSPs) in sanitation services in Kibera, a low income settlement in Nairobi, Kenya. There is a great disparity in their revenues but they compare favourably to the minimum wage for general labourers in Nairobi. This figure highlights the important commercial potential of the sanitation sector, and the need for government to recognise and support the business opportunities as well as the contributions made by PSSPs in extending services to the poor (Bongi, Morel 2005). According to the WHO (2006), the potential for strengthening the roles of private entrepreneurs in the safe management of FS exists. The policy framework should facilitate their role in providing safe services.

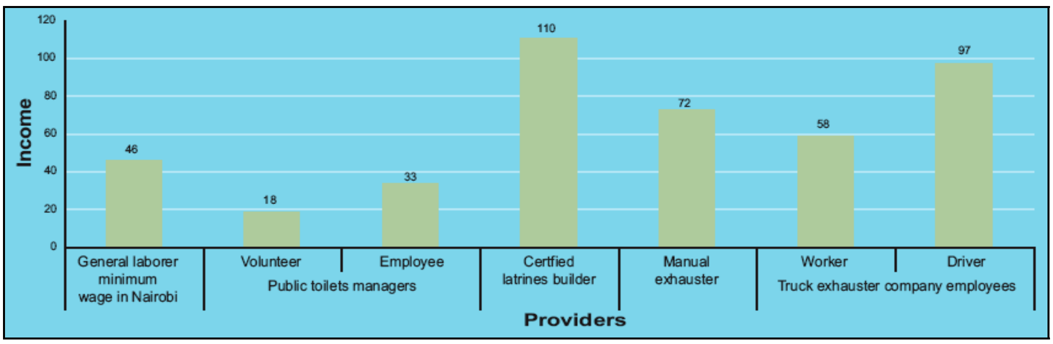

Figure 21: Average monthly revenue of private small scale service providers in sanitation services in Kibera, Nairobi (in US$) (Bongi, Morel 2005)

Table 12: Potentials, limitations and restrictions for private small-scale enterprises in waste management and sanitation

Potentials	Limitations and restrictions
– The services offered are tailored to the special demands of poor target groups who have no or only limited access to public waste management services. – Services can be quickly and flexibly adjusted or extended according to demand. Financing for equipment and/or other small investments can usually be obtained quickly and easily. – Small-scale enterprises are often able to develop and offer appropriate services even in difficult situations (e.g. difficult to access sloping sites, flood-prone areas, settlements with seasonal demands or low turnovers etc.). – Poor target groups are willing to pay cost-recovering fees when service quality and charges correspond with their expectations and capacity to pay. – Profits are generally re-invested to extend or diversify services, or to explore new business opportunities.	– Insecure service continuity: Services are only maintained as long as they are profitable or so long as the service provider does not develop other more profitable business opportunities. – Potentially high user fees: In order to operate profitably, fully cost-recovering fees are necessary. Fees must also include a profit margin to hedge against operational risks and to allow for future investment. – Poor household may distrust private service providers who are primarily profit-oriented. – Service commissions and orders are often insecure, temporarily and only informally agreed upon; written contractual arrangements are the exception. Long-term continuity and reliability of service provision is thus difficult to guarantee. – Public sector supervisory bodies often do not acknowledge or hinder investment by small-scale enterprises, especially those by informal enterprises. – Difficult access to formal sector financial services, especially to credit, hinders investment for service extensions and/or the maintenance and repair of equipment. – Small-scale enterprises are often disadvantaged in public tenders for waste management services. – A lack of dialogue and communication between responsible public sector institutions and small-scale enterprises impedes the development of specific service offers for poor target groups.

Source: (Bockelmann, Samol 2005)

Table 12 shows potentials of private small-scale enterprises in waste management and sanitation, as well as limitations and restrictions for these enterprises.

Public-private partnerships

One of the difficulties in defining the scope of private sector involvement in water and sanitation is the diversity of possible partnership arrangements and potential actors. These can range from: complex concession arrangements lasting thirty years through to service delivery by small-scale independent providers who are local entrepreneurs.

The focus here is on the more complex contractual relationships in the context of formal contracts, such as concessions and leases, which are widely believed to provide the best opportunity for the public sector to benefit from the full resources of the private sector (Sohail 2003).

PPPs may be broadly defined to include a spectrum of possible relationships between public and private players for the cooperative provision of infrastructure and / or services. Their use in sanitation promotion would be relevant in two contexts. The first covers the private sector's ability to tap markets for sanitation or hygiene related products (such as soap, toilet construction or toilet parts, toilet cleaning and FSM methods and products). Secondly Private sector involvement also has the potential to improve efficiency and quality of service delivery (Mehta, Knapp 2004).

Vives et al. (2006) say that water and sanitation is the most complicated of infrastructure sectors regarding PPP: In general, because of the political implications, the perceptions that these services are a right, the social consequences of deficient services, the fact that most of these services are provided at the local level, and difficulties in cutting-off service, make this sector one of the hardest to finance and one of the riskiest investments for the private sector.

Sanitation is considerably less procured within PPP than water-supply. Part of the problem is due to a lack of demand on the part of users, resulting from a lack of awareness of the health risks of inadequate sanitation facilities and thus leading to a lack of demand and willingness to pay for this service, especially when many people have managed without it for years. As private providers will only become involved in sanitation provision on the understanding that users will cover the full cost, a lack of demand on the part of the users translates into a lack of provision in practice. (Budds 2000)

However, if demand and capacity and willingness to pay are given, resource-oriented sanitation can be more attractive for the private sector than conventional sanitation. Infrastructure costs are normally lower than for conventional options (no sewerage) and the additional benefit of fertiliser sale may stimulate private-sector involvement. In chapter 4.7.5 (Public-Private-Partnerships) more information on financial issues related to PPP arrangements will be given. Figure 22 illustrates the public to private continuum for private sector participation in infrastructure development, ranging from fully public to fully private (full divestiture) schemes.

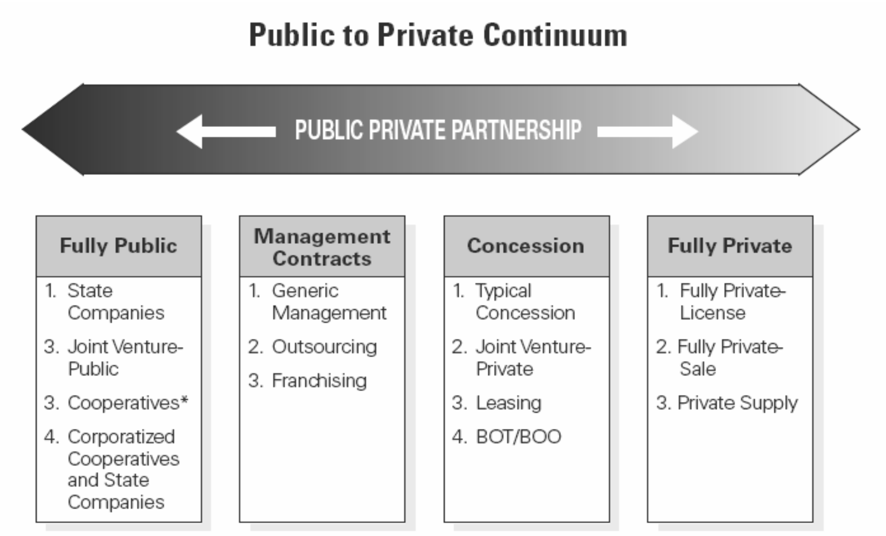

Figure 22: The public to private continuum (Vives et al. 2006)

Table 13 summarises PPP options. According to UNEP (2004), the described service and management contracts and simple lease structures have proven to be rather successful tools in improving operational efficiency. However, they do not provide a means for service expansion or upgrading, for which substantial amounts of capital are required. Options like concessions, Build-Own-Transfer (BOT) contracts, and (partial) divestitures are means to raise funds for such investments. Variations on the BOT model include: BOO (Build-Own-Operate: assets are not transferred); ROT (Rehabilitate-Operate-Transfer: investment in rehabilitation); Reversed BOOT: government responsible for asset construction, private company for operation; DBO (Design-Build-Operate: private company also conducts investment design).

Table 13: Types of cooperation in public-private partnerships

Type of partnership	Characteristics	Constraints
Service contracts Specific components are contracted out to private sector; government retains responsibility for O&M.	Examples are: operation of a treatment plant, billing, and collection operations.	
Management contracts Responsibility for entire O&M is transferred to contractor.	Payments can be a fixed fee, but are usually related to achievement of performance targets. This creates an incentive for increasing productivity.	Setting, monitoring, and evaluating targets difficult. Achievement of targets may be related to capital investments, which are not the responsibility of the private contractor.
Lease contracts Private operator is responsible for operating, maintaining, and managing a system, incl. revenue collection for rented assets.	Government remains sole owner of assets and is responsible for expansion and upgrading, investments, debt service, tariff setting and cost recovery policies.	Particularly beneficial if no substantial capital investments are required, and thus not popular in wastewater management sector.
Concessions Concessionaire has full responsibility for delivery of services: operation, maintenance, system expansion, collection of revenues and fundraising for investments. Government responsible for establishing and enforcing performance targets.	Concessionaire has strong incentives to make efficient investment decisions and to develop innovative technological solutions, since efficiency gains will directly increase its profits. Full utility concessions are attractive where large investments are needed to expand coverage of service or to improve quality.	A critical factor is quality of regulation, as it concerns a long-term monopolistic position of concessionaire.
Build-Own-Transfer contracts Private sector finances, builds, and operates new facility applying governmental performance standards. Government retains ownership of facility. In construction period, private sector provides investment capital. In return, government guarantees purchase of a specified output.	Operation period should be long enough for contractor to recover its construction costs and to realize a profit. Agreements mitigate commercial risks for private sector, because government is its only customer. Thus, BOT contracts are financed with a relatively high debt component.	Not for existing infrastructure: they do not tackle deficiencies nor do they turn financially weak utilities into strong ones. Length and complexity: most BOTs have to be renegotiated once underway. Size and time frames often require sophisticated and complicated financing packages
Divestiture Full divestiture pertains to a situation where utility has been fully privatised. Ownership of utility rests with private operator. Private operator is responsible for O&M, investments and tariff collection. Regulation (to safeguard public interest) in hands of Government, so completely separated from ownership and operation	Improved incentives for efficient investment decisions and development of innovative technologies. Low transaction costs compared to costs of tendering and contract negotiations associated with models discussed above.	Possible conflict of interest: public sector responsible for regulation and company shareholder responsible for maximizing returns. Could lead to political interference and counteract private sector management advantages. No competition (as no tendering) can raise transparency and corruption concerns.

Source: (UNEP et al. 2004)

Table 14 below shows the allocation of key responsibilities for each main option. It can be seen that O&M tasks are almost always assigned to private service providers in PPP cooperation types. If only O&M responsibilities should be assigned to a private sector company, this can be done either through a lease or a management contract.

Table 14: Private sector participation: Allocation of key responsibilities

Option	Asset ownership	Operations & maintenance	Capital investment	Commercial risk	Typical duration
Service contract	Public	Public & private	Public	Public	1-2 years
Management contract	Public	Private	Public	Public	3-5 years
Lease	Public	Private	Public	Shared	8-15 years
Concession	Public	Private	Private	Private	20-30 years
BOT/BOO	Private & public	Private	Private	Private	20-30 years
Divestiture	Private or private & public	Private	Private	Private	Indefinite (may be limited by license)

Source: (UNEP et al. 2004)

In chapter 4.7.5 financial and pro-poor issues of PPP will be discussed. Furthermore a guideline for the financial structuring of PPP infrastructure investments in the water and sanitation sector is presented. It can be used to find the right modality for the PPP arrangement based on the local conditions and available risk mitigation tools.

4.5.6 Cooperative Association of Public Administration

The cooperative association is an organisation in private law, which aims at solving a social need through the production and provision of a service. It is composed of associates including: users of the service, representatives of local authorities, representatives of other associations or public/private firms. It is created the following way: After an authorisation obtained from the Municipal Council, a General Assembly composed of all the associates elects the members of the Governing Board, approves the charter and regulations, establishes policies and programmes, and gives the general orientation. The Governing Board is the permanent body for the management and administration of the cooperative association. It will nominate or remove the manager, determine the profile for the staff, propose the budget for control (which will have to be approved by the General Assembly), and convene the General Assembly. It is composed of a President, Vice-President, a Secretary, and a Controller who are elected for a period of one year. The cooperative association of public administration is organised the following way (Brikké 2000):

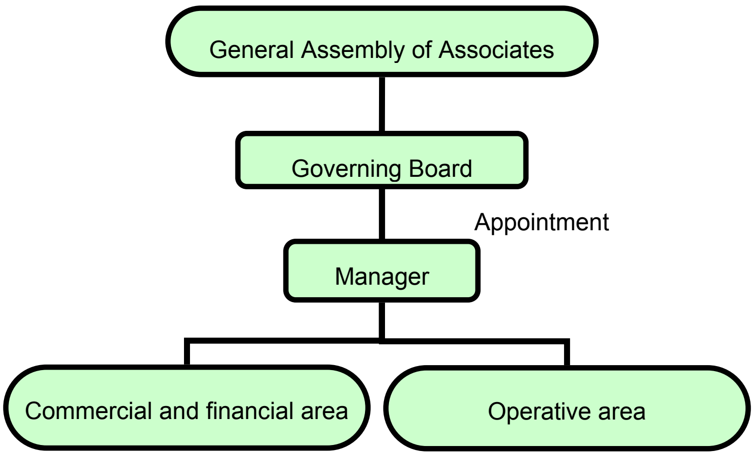

Figure 23: Cooperative association of public administration (Brikké 2000)

4.5.7 Monitoring O&M

The concept of monitoring the performance of O&M and using the results to improve the situation is not widely known or practised in many countries. This is surprising, as monitoring and evaluation are important means to ensure the continuous success of an O&M system. Without measuring and evaluating performance, problems in O&M are often detected too late, leading to poor performance of the whole service or even major breakdowns. Continuous improvement of O&M is furthermore only possible if the O&M arrangements and stakeholder performances are assessed regularly. Even if O&M works perfect it is good to know why it is so – this way valuable information on the issue of O&M can be analysed and shared with others.

The WHO (WHO 2000a) has developed a set of nine tools[36] to help overcoming problems with the O&M of WSS in both rural and urban areas of developing countries. The document proposes a framework for management and tools for assessing the status of O&M through measurement and evaluation of performance. Performance is measured using carefully selected indicators to assess the status of O&M and to highlight successes and failures. Managers can use the information on performance to help them formulate policy and implement plans which are relevant to the problems that have been exposed.

Operational monitoring addressing O&M performance should also regard the importance of pathogen control. Bad performance of O&M can have very negative impacts on public-health and the environment. For operational monitoring in regard to pathogen control, the 'WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater; Volume IV: Excreta and Greywater Used in Agriculture' (2006) are recommended. On pages 104 – 106 operational monitoring is addressed and some parameters for monitoring are given.

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[36] WHO. *Tools for assessing the O&M status of water supply and sanitation in developing countries,* World Health Organization. Geneva, Switzerland, 2000.

Key Issues

Experiences with local management models are limited. However, several basic concepts do exist. Management options consist in a blend of ownership and responsibilities between the public sector, the private sector and user associations. Appropriateness of a management model highly depends on the local conditions and a careful assessment of them is necessary. Management by the local authority is only possible where the capacities are given and the chosen arrangements can supply all areas and communities with adequate services. Alternative models exist - they cannot operate in total isolation, but need support from the local government. Community involvement in management is desirable; however, several constraints do exist for community management, especially in urban areas. Voluntary contributions to O&M normally reflect the sense of ownership and the level of benefits accrued on the individual level. Community willingness, capacity and skills have to be assessed before assigning responsibilities. Private sector involvement is already prevalent in the sanitation sector in most towns. Entrepreneurs' role has to be strengthened by an appropriate policy framework and informal providers have to be recognised, regulated and supported by the government. PPPs offer a wide spectrum of possible formal contractual arrangements - O&M is usually the private-company's responsibility in this arrangements. Each arrangement has pros and cons, whereas the main constraint for private involvement is the matter of difficult cost-recovery in sanitation. Management by associations is a form to involve several stakeholders in one management system. Monitoring and evaluating O&M is necessary to guarantee sustained success – performance and pathogenic risk assessment are amongst the objectives.

4.6 Cost Recovery

4.6.1 Introduction

‘Lack of money’ is often said to be a principal constraint to providing water and sanitation services. In many cases, the problem is not only the lack of money but also mismanagement of resources and a reluctance to pay for the service (Brikké 2000).

A key factor of institutional capacity is the degree to which the service organisation is financially autonomous and freed from the national budget. Authorities or agencies that derive the bulk of their revenues from user payments possess the greatest stability (UNEP 2002). Saywell and Cotton (1998) also argue for a central role to be given to user charges with regard to financing. This means that users are encouraged to contribute according to their willingness and ability to pay for the services. The rationale for this approach is based on the lessons learnt from previous city wide, donor financed projects. “Typically, these schemes were dependent on widespread subsidies to get projects off the ground because it was assumed that users did not have adequate means to pay. The consequence was unsustainable interventions.” (Saywell, Cotton 1998).

Theoretically, the long-term goal may be to reach full economic pricing, where users pay for the environmental and social costs of expanding the system. In reality, achieving even moderate levels of cost recovery shall be considered a success (Deverill et al. 2002). Cost recovery in wastewater management is generally quite poor and, even where sufficient monetary resources exist, there is often little willingness to pay for improved wastewater disposal (Parkinson, Tayler 2003).

According to Brikké and Bredero (2003), the recent trend is to ask the users to pay for many of the direct and local-level costs of O&M. Additional funds are also required to provide agency support (e.g. for training and monitoring). In many cases support costs are subsidised by the government and external agencies. However, if sustainability is to be achieved, full coverage of O&M costs should be the goal to be pursued. Communities are expected to contribute both the direct and support costs of O&M, especially if replacement costs have to be included. It is thus important to plan and decide on financial mechanisms that would cover all costs, if these cannot be covered by user’s fees, and especially when there are big repairs or replacements to pay for. Alternative financial resources, other than user payments will be discussed in chapter 4.7.

It always has to be kept in mind that many more factors than financing alone come into play in achieving sustainability of improved services. In many cases, failure to appreciate this basic point lies at the root of many failed attempts to introduce user payment for the services. Recovery of costs does not always have to be in the form of cash. A very large number of WSS projects recover at least part of their costs through user contributions of labour and local materials, a feature frequently found in projects based on community participation. Such contributions may account for as much as 20-30% of capital costs, and an equally high proportion of the costs of O&M (Evans 1992).

4.6.2 Financial Aspects and Cost Estimates of Urban/ Peri-Urban Ecosan

There is little experience with cost-recovery in large-scale Ecosan programmes. However, Ecosan has distinctive financial differences to conventional sanitation. Hence, at first some financial characteristics of Ecosan have to be highlighted.

Sanitation systems that recover excreta and greywater for re-use generally have a different cost structure. The total costs to install and operate such systems tend to be lower than for more conventional sanitation systems. This is mainly due to the decentralised, modular nature of source separating systems, which do not require large sanitary infrastructure, such as centralised treatment works, sewerage, or pump stations. In comparison with traditional decentralised sanitation (such as pit latrines), they normally provide more permanent solutions and thus do not have to be replaced when full, representing an incremental saving over an extended period of time (WHO 2006).

However, an urban eco-san system will generate additional costs that are not usually present in small rural Ecosan projects. For rural areas, the distances between households and agriculture are very short, and transport and storage may therefore have a negligible impact on the overall cost. But for urban situations logistics may have significant cost implications. Another consideration is that whilst the household facility can be designed for individual households, collection, treatment and transport should be designed to cover a number of households to achieve economies of scale (Münch, Mayumbelo 2007).

Furthermore, costs for information, training and follow-up have to be considered in the urban (and in the rural) context. On the other hand, the economic value of the fertilisers produced could be significant (Winblad, Simpson-Hérbert 2004).

Cost estimates

It has been observed that different authors have used varying approaches for sanitation system cost-estimates. Differences are significant, for example regarding the components included in their costs estimates. Furthermore, the estimation of recurrent costs seems to be problematic due to the lack of easily available data sources. In a full economic cost-estimation health benefits and environmental protection/ pollution have to be considered. The setting of the boundaries of system often leads to many external costs or benefits being overlooked. However, health benefits and environmental externalities are difficult to value and can often be assessed qualitatively only.

Rockström et al. (2005) set up a sanitation cost system that consists of investment costs and O&M costs for the first year of operation. They state that Ecosan alternatives (including collection, transportation and treatment) cost much less than conventional solutions (sewer connection and wastewater treatment). However, urban Ecosan seems to be 5-10 times more expensive than rural Ecosan (but still cheaper than conventional sanitation) since greywater needs to be collected and treated using decentralised treatment facilities. Also additional costs for transportation of the various products to local ‘ecostations’ for treatment and storage as well as to agricultural sites for recycling have to be considered (Rockström et al. 2005).

The authors do not state whether O&M in their calculations includes desludging, treatment and associated costs. Although they carry out an analysis of the commercial value of N and P from human excreta, they do not indicate how exactly this benefit can reduce the household or per capita cost of the sanitation system. Furthermore Mara (Mara 2006) states that Rockström et al. (2005) compare Ecosan costs with the costs of conventional sewerage, but not with those of simplified (or condominial) sewerage. Mara says that there are good costs for condominial sewerage in Brazil and also for low-cost sewerage in slum networking projects in India. He argues that simplified (or condominial) sewerage is often the cheapest solution for peri-urban and urban areas. However, these technologies require at least a basic amount of water to function and may not be suitable for water scarce regions.

Hutton and Haller (2004) are the authors of a report entitled ‘Evaluation of the costs and benefits of water and sanitation improvements at the Global level’ for the WHO. The aim of this report is to show that water and sanitation interventions result in improved public health and other non-health related benefits for society. Hutton and Haller (2004) give a comprehensive financial analysis done at global level considering water, sanitation and health aspects. Their costs include all costs that are necessary to put an intervention in place and maintain it as well as the costs that result from an intervention. Subsequently they have very high figures compared to Rockström et al. (2005).

Figure 24 illustrates tentative cost estimates (for financing wastewater collection and treatment in relation to the MDGs) for different levels of sanitation service and technology options, conducted by the United Nations Environment Program (UNEP 2004). The estimate is presented as a ‘ladder of sanitation options’ starting at a basic level and moving up to higher levels of service. It is clearly illustrated that there is an important difference between the (mostly non-networked) rural sanitation component of the target on sanitation and the (mostly networked) urban improved wastewater treatment component. The figure shows that decentralised Ecosan technologies can be considered as cost-effective alternatives to traditional centralised approaches, also in densely populated urban areas. All given costs include O&M costs as a percentage of investment costs (15%), but the authors do not say how these costs were calculated for the Ecosan estimates.

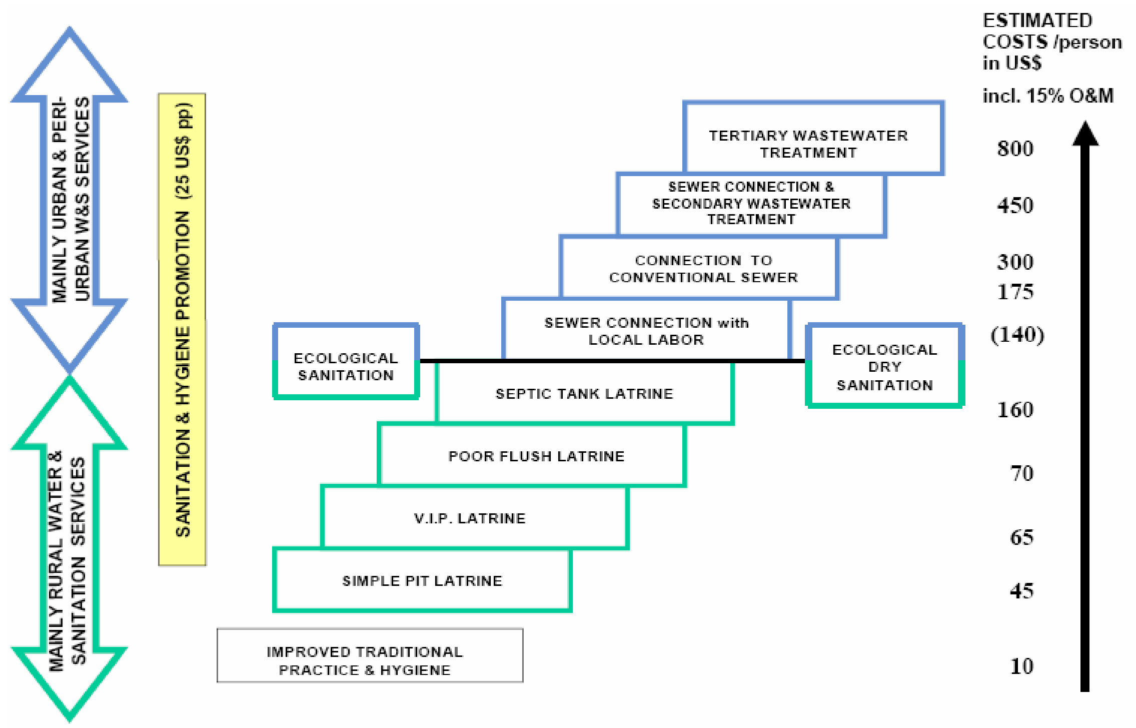

Figure 24: Cost considerations - A ladder of sanitation options (UNEP 2004)

Münch and Mayumbelo (2007) propose a methodology to compare costs of sanitation options. They compare the costs for conventional on-site sanitation with urine diverting dry-toilets as a sanitation solution for low-income peri-urban areas in Lusaka, Zambia. Their estimate covers the whole sanitation systems (household toilets, collection and transport of excreta, treatment and storage, and transport of sanitised excreta to reuse sites). The authors, however, did not account for expenses for information, training, monitoring and follow-up. These expenses are difficult to calculate but will definitely have to be considered in the planning stage. The following observations were made by Münch and Mayumbelo (2007) regarding the operating costs:

- The operating costs of both options are basically the same.
- The sale of urine has potential to generate a significant income due to its N and P content whilst being virtually pathogen-free. However, the achievable sales price for urine requires further investigations.
- The largest contribution to the operating costs originates from excreta collection and transportation to treatment plants for both options.

<u>Financial viability of urine harvesting in urban Ecosan</u>

Münch and Mayumbelo (2007) found that the transport cost of the urine barrels turned out to be very high. This was also discovered in Tepoztlán, Mexico, where a large.scale peri-urban urine harvesting was implemented: „Household collection of urine is not logistically or financially viable at the present time in small towns of 20-50 thousand, where large communal housing developments are still uncommon." (Sarar Transformación SC 2005). Mayumbelo (2006) found urine storage in non-growing seasons is another crucial point regarding the financial viability of a large-scale urine harvesting programme. These findings are no surprise when looking at the amounts of urine produced daily. One person produces about 1.5 litres of urine a day - this means that a town of 500.000 inhabitants produces about 750m³ of urine per day. A discussion about urine storage possibilities flared up in the EcosanRes mailing list[37] in spring 2006 (found in: (Mayumbelo 2006)). Some experts proposed to store the urine in the soil during the non-growing season if climatic conditions are suitable (no excessive rain). Another possibility could be the use of cheap storages facilities like dams or ponds covered with rubber or plastic liners. The major logistical, financial and cultural problems of large-scale urine harvesting have not yet been solved for low-income areas. Sawyer (2005) recommends for Tepoztlán in Mexico, that domestic urine will be best disposed of on-site (e.g. added to household compost, orinoponics, mixed with greywater; and direct application to trees, lawns and gardens.) - and, possibly, transported short distances to neighbourhood eco-station composting facilities. Transport in small-bore pipes, together with greywater, could be an alternative option in some cases but may be more capital cost intensive (Münch, Mayumbelo 2007).

Revenues from recyclates

Waste can only become a resource if this resource is needed and if it is socially acceptable (Heeb et al. 2006).

Vodounhessi and Münch (2006) write that a study on the willingness to pay for compost made from FS and solid waste in Kumasi, Ghana, found that all farmers who currently used conventional compost, and 83% of the non-compost users, perceived municipal co-compost as positive or 'good' material for soil amelioration and crop growth. In addition, about 70% of them said that they were willing to pay for it. Based on the reported farmers' willingness to pay, the authors estimated that at a compost price of € 1.1 per 50 kg bag, all the produced compost would be sold.

Drechsel et al. (2004) conducted a comparative survey of composting stations in West Africa. They state that revenues from compost sales and organic waste collection did not cover the running costs and certainly not the set-up costs of the stations. Stations are only viable where compost can be sold at a relatively high price while labour, capital, and land inputs are free or marginal. This appears only possible in small neighbourhood initiatives with identified compost demand. The economic analysis showed that without subsidies, only few farmers, mostly in compost station vicinity, could afford to pay for compost and transport[38]. Scenarios assuming a fully subsidised production still showed spatial limitations in compost dissemination due to transport

[37] http://groups.yahoo.com/group/Ecosanres - see chapter2.1.1

costs. The authors say that these limitations showed clearly that the idea to 'close the rural-urban nutrient loop' is not realistic. "While it is feasible to transport high value (food) products over long distances and different middlemen into the city, it is not feasible to transport a low value product the same way back." (Drechsel et al. 2004).

The price paid for urine is about € 0.15 per 20 L jerry can in Ouagadougou, Burkina Faso, according to Münch et al. (2006).

The forecast of sales revenues is a critical factor in the calculation because it strongly influences the financing model. Generally it can be said that one should be conservative when estimating the sales revenues. Economic pressures from the competitive marketing of fertiliser can constrain the re-use of excreta, particularly where cheap alternative nutrient sources in the form of artificial fertiliser are available. For the case of decentralised composting Rothenberger et al. (2006) give a comprehensive guideline for designing a marketing strategy and for how to carry out a market analysis.

4.6.3 Capacity and Willingness to Pay

Users' capacity to pay[39] and willingness to pay for sanitation services must be considered one of the most important pre-requisites for long-term sustainable operations. While the capacity to pay mainly depends on the price of the service and users' economic circumstances, i.e. their disposable household incomes, willingness to pay is largely determined by service quality and its impact on living and housing conditions. The poor will often be willing to pay for improved services. However, if they do not have the capacity to do so, willingness to pay is not more than an expression of demand.

Users of sanitation services are usually only willing to pay fees or make their contributions, when they see a significant improvement of service quality (Bockelmann, Samol 2005). Where there is no alternative choice, the willingness to pay may be quite high. In contrast, improved sanitation services may not be used if there are disposal possibilities nearby and the cost of the sanitation service is considered high.

Capacity to pay

As a general rule of thumb, it has been said that people should not have to pay more than about 3-5% of income for water and sanitation services. However, cases have been found of impoverished people paying far more than 3-5%, sometimes as much as 20-30% of meagre annual incomes (Evans 1992).

Some 300 million people in Sub-Saharan Africa - almost half of the region's population - live on less than US$ 1 a day (UNDP 2006). The most which an individual earning US$1 a day could afford to pay for water and sanitation, according to the 3-5% criterion, would be US$ 18 per year. For the 300 million people below this level of income,

[38] A significantly higher demand for compost than from urban and peri-urban agriculture was estimated from landscaping and estate development around the three cities covered by the survey (Drechsel et al. 2004)

an annual contribution of even US$10 per person per year is likely to be beyond ability to pay. Keeping in mind that water in low-income settlements (which is mostly delivered through water-vending) is very expensive to buy, there is probably not much left to spend for sanitation. Thus, a sanitation intervention, which is accompanied by provision of affordable water-supply services, will have better chances of cost-recovery as the capacity to pay for sanitation is increased.

Willingness to pay

According to Evans (19992), from an economist's point of view, demand is only real (or 'effective') when it is accompanied by willingness to pay, in cash or kind, for the services offered. Willingness to pay depends on a number of factors which are presented in the Figure below.

Factors influencing willingness to pay

- Service level
- Service standard
- Perceived benefits
- Relationship to production
- Level of income
- Price
- Characteristics of existing sanitation
- Reputation of service agency
- Community cohesion
- Policy environment
- Socio-cultural factors
- Perception of ownership and responsibility

Figure 25: Factors influencing the willingness to pay; adapted after (Evans 1992)

Assessment of willingness and ability to pay

Willingness to pay and ability to pay for services should be assessed and not assumed. Willingness and ability to pay are often assumed, based on income levels or general demographic indicators. "However, there is a large and growing body of research that clearly indicates that those who are often assumed to be unwilling or unable to pay, in fact are, when provided with a range of different technological and financial options along with knowledge about the possible impacts and implications of the options and their prices." (Cardone, Fonseca 2003). Once the expected outcome is understood, financing mechanisms can be generated to meet the outcome at a cost that is affordable to the consumers. Brikké (Brikké 2000) names a number of methods to measure willingness to pay:

[39] Also called 'ability to pay'

Indirect measures

- Factors can be assessed by means of socioeconomic surveys or monitored throughout a project.
- These will provide some trends in the willingness to pay, but are not always totally correlated.

Direct measures

- Assessment of the direct financial contribution of communities for the construction and investment of a sanitation facility.
- Often not suitable because the community may be willing but unable to pay.
- Another direct way of measuring is to calculate the percentage of payments received, to the total payments due. The lower the percentage, the lower the willingness to pay.
- In this case, the results do not give any information about the reasons why people decide to contribute or not. All direct measures have this problem.

Hypothetical behaviour studies

- Ask users what would be their choice of service available at a specified price. This is called the contingent valuation method, since user responses are contingent, or dependent, on predetermined conditions. Lack of available data and non-rational economic behaviours are severe constraints to this approach.
- The bidding game method is a negotiation between the interviewer and respondent, moving within a range of potential prices for a water supply improvement until bidding settles at a final value. This method causes some problems because responses could be influenced in some way by the interviewer. The answers about willingness to pay are always around the first price mentioned or starting point of the survey.
- The referendum method is more suitable because people act as they do in a market place (with a given price, they decide whether to buy or not).

Actual behaviour study

- Actual behaviour studies assess the present payment behaviour of consumers, such as cash payment to pit emptiers, direct cost savings, indirect cost savings (calories, time, money). One problem is that the actual behaviour assessment requires a long period of study because it is difficult to know what people will do, and it requires considerable expertise.

Maximising willingness to pay

The key factors for success in the willingness to pay for improved sanitation services are (Sawyer et al. 2003):

- Community members make informed choices, based on:
  - Their participation in the project.
  - Technology and service level options, recognising that more expensive systems cost more per member.
  - When and how the services are delivered to them.
  - How funds are managed and accounted for.
  - How their services are operated and maintained.
- An adequate flow of information is provided to the community and procedures are adopted to facilitate collective decisions within the community and between the community and other actors.
- Governments play a facilitative role, set clear national policies and strategies, encourage broad stakeholder consultation, and facilitate capacity building and learning.
- An enabling environment is created for the participation of a wide range of providers of goods, services, and technical assistance to communities, including the private sector and NGOs.

Optimising willingness to pay requires a strong link with users, which relies on a proper information flow on both sides. Consumers have the right to know about the quality of service and the provider has the obligation to resolve the user's complaints and keep them informed. The following questions are related to optimising the relationship between users and the service provider (Brikké 2000):

- Does the provider have a mechanism to deal with consumer's complaints?
- Does the provider give complete information to users about the sanitation service?
- How does the provider get to know the users' opinions about the level of service?
- Does the provider have indicators to measure the quality of the service provided to users? How are these indicators used?

There is a tendency today to ask communities to contribute to the initial investment costs, as a way of strengthening their financial responsibility and future willingness to pay (Brikké 2000).

4.6.4 Financial Responsibilities

There is a need to define clearly the financial responsibilities of stakeholders, including the community, national government, local authorities, NGOs, donor supported projects, donor programmes, and possibly others such as churches, individuals or the private sector. Defining financial responsibilities includes determining who is financially responsible for which costs, and over what period of time. While 'cost sharing' arrangements are now widely accepted, they will also require that all parties define precisely the boundaries of their responsibilities, and that these are sealed in an agreement or a contract (Cardone, Fonseca 2003).

Brikké and Bredero (2003) propose that the financial responsibilities for a system should be linked with the management and/or operational responsibilities. This will mean that for each task required to manage, maintain and replace, there is someone responsible for implementing the task, and someone responsible for financing it. It may take time to transfer responsibilities during the transition period to a linked system, and this should be taken into account in the planning process.

Table 15 shows how for example administrative tasks and support activities can be distributed between the community and the government agency or NGO. The community can assume operational and financial responsibilities for most of the tasks that are directly related to the community, or fall within the community's boundaries. However, government agencies or NGOs normally have operational responsibility for all support activities. In some projects communities have also been asked to pay for support services once the project was handed over. In the next step, the distribution of operational and financial responsibilities should be formalised in an agreement or contract that describes the rights and obligations of each party, and defines sanctions or mechanisms for non-respect of the agreement.

Table 15: Distribution of responsibilities for administrative and support activities linked to O&M

Administrative and support tasks linked to O&M	Operational responsibility	Financial responsibility
– prepare annual budgets and long-term financial estimates; – analyse O&M tasks for use in planning and budgeting; – collect, analyse and monitor results, and conduct follow-up support or training, as required.	Community and govern-ment	Community and govern-ment
– develop and evaluate technical and management training for water and sanitation system operators; – develop and evaluate financial and management training for community managers; – provide technical training for operators; – provide financial and management training for community managers; – develop simple information materials on hygiene education; – provide technical and management support to community managers.	Government/ NGOs	Government/ NGOs
– select and appoint operators/contractors for O&M; – delegate task responsibilities; – supervise and pay salaries; – keep archives, inventories and log books; – collect fees and manage revenues; – make payments for purchases, loans and other obligations; – respond to users' complaints; – organize and conduct general meetings for discussions; – hold elections; – organize community contributions for upgrading or extending the system; – report urgent problems to the government agency.	community	community

Adapted from: (Brikké, Bredero 2003)

4.6.5 Operation and Maintenance Costs

Identify costs

Before thinking of cost recovery, the costs have to be identified. The importance for identifying O&M costs and the difficulties to do so are expressed by the following citation (related to water-supply):

"If the estimate is too high, the planner and the users may conclude that the community cannot afford the system; if the estimate is low and the water system is constructed, the system is likely to fall into disuse or disrepair due to lack of funds for its O&M. Though the need for accurate cost estimates is clear, a methodology for making such estimates had not been developed" (Evans 1992)

Compared to investment costs, operating costs are generally more difficult to determine because they are influenced by a multitude of factors, the majority of them non-technical. As with investment cost, the parameters determining operating costs can vary considerably according to country or project-specific conditions. Moreover, depending on the type of technology selected, different kinds of cost may need to be considered. But even for technologically similar solutions, the specific environmental conditions of a project location can cause very different operating costs. In most cases, it will not be possible to refer to reliable rules of thumb or a comparison of similar projects in different countries or regions. Typical operating costs for sanitation projects consist of costs of, for example (Bockelmann, Samol 2005):

- material and consumables;
- spare parts and small pieces of equipment;
- staff (operational, administrative, maintenance etc.);
- administration and management;
- energy;
- repair work and replacement of equipment;
- external consultancy and engineering services (e.g. technical assistance, accounting, auditing, coaching, etc.);
- supplementary depreciations;
- financing (e.g. interest on loans, other capital cost)

There are several ways of costing services, which include (Deverill et al. 2002):

- Routine O&M, excluding major repairs
- Full O&M costs
- Full O&M costs plus a proportion (percentage) of capital costs. Capital or investment costs are those costs associated with the intial provision of infrastructure
- Full O&M costs plus a percentage of capital costs and a proportion of replacement costs.
- Full O&M, capital and replacement costs
- Full economic costing, taking into account any environmental and social costs (e.g. incurred by down stream users being deprived of a water source) and the cost of expanding the system in future. Whilst it is unlikely that users would be able to pay for the full economic costs, it is a good method of comparing different options.

To estimate routine O&M costs (basic recurrent costs), Brikké (2000) proposes the following procedure:

- List all O&M activities needed and their frequency.
- According to each activity, list all human resources, materials, spare parts, energy, tools and equipment required.
- Estimate the quantity or volume needed for each requirement.
- Define the activity cost.
- Sum up all costs of all activities.

This estimation does not include such elements as depreciation, replacement costs, initial capital reimbursement, training costs, environmental protection costs, etc. Depending on the strategy and policy of the project, these additional costs may have to be added.

Reducing O&M costs

The managers should also be made aware about ways to optimise or minimise costs related with the technology used such as:

- Economies of scale;
- Reduction of dependence on energy and chemicals;
- Monitoring changes in fixed and variable costs;
- Improving preventive maintenance and therefore fostering a 'maintenance culture' within a community;
- Installing a systematic control system for damages and breakdowns;
- Developing an effective financial control mechanism.

Locally-based supply chains can help to keep the cost of spare parts and other supplies – and therefore maintenance – at affordable levels, while at the same time providing employment opportunities within communities (Cardone, Fonseca 2003). Reducing the dependence on fuel or electric consumption through either low-energy technologies and/or by using alternative energy sources (e.g. solar-energy) may further minimise costs.

4.6.6 Setting an Appropriate and Equitable Tariff Structure

According to the UNEP (2004), any sustainable sanitation management system must address the key issues of financing and cost recovery on the one hand while ensuring equity on the other hand. Tariff rates for sanitation can have important equity and environmental implications. In many areas, tariffs are set universally low to avoid the political consequences of full-cost pricing, or the justification is that prices should be set so that the poorest family can pay the charges. Funds to cover the revenue shortfalls in these situations must come from general resources, or the needed O&M will not be carried out. These situations result in effective subsidies for each litre of wastewater discharged, ironically resulting in large subsidies going to large wastewater producers such as industries and wealthy families. Artificially low prices furthermore mask the economic cost of those services. For example, when the price of wastewater disposal is set lower than the cost, more wastewater is released into the environment than would be released if the price reflected the cost (Rosensweig, Perez 2002).

Nonetheless, it is often difficult for users to be able to adapt to non-subsidised prices which reflect the full cost of the service. In low-income areas targeted subsidies may be necessary creating a flow from the affluent part of society to those who cannot afford service costs. But even in low-income situations improvements can be affordable. Households may be willing to pay for in-house sanitation facilities and for facilities that remove excreta or wastewater from their property. However, individual households often do not directly perceive more aggregate level benefits from sanitation services (UNEP 2004). Nevertheless, awareness can be created to achieve that, at a block, neighbourhood or city level, households will collectively place high value on services that remove excreta from their area as a whole. On the macro level, waste discharged from one city may well pollute the water supply of a neighbouring city. Costs assigned to each level in the household-neighbourhood-city hierarchy should be in accordance with benefits accruing at each level, as described here:

- Households should pay for most costs for on-site facilities
- Residents of a block or neighbourhood should collectively pay costs of transferring collected waste to the boundaries of their block or neighbourhood (and treating the groups' waste).
- Residents of a city should collectively pay additional costs of collecting waste from neighbourhoods and transporting these to the boundary of the city for treatment. (UNEP 2004)

In urban poor settlements, full and comprehensive cost recovery will rarely be possible. A realistic minimum should, always cover all running and recurrent operating costs. From this starting point, attempts can be made to gradually work towards full cost recovery (Bockelmann, Samol 2005). If the level of recovery from fees can only cover part of the operating costs, the financing shortfall will have to be met from other financing sources, e.g. from local or central governments (see chapter 4.7: Alternative Financial Sources).

The 'polluter pays' principle

The 'polluter pays' principle was included as a principle in the Rio Declaration. Its use through economic instruments such as polluter/sewerage charges in the context of sanitation would help provide economic incentives to reduce pollution and generate revenues to meet the costs of sewerage and wastewater treatment (Mehta, Knapp 2004). The polluter pays principle is the requirement that the person responsible for pollution should bear the costs required in response to such pollution so that these are internalised rather than imposed on the society as a whole. This principle should be applied in a socially acceptable way, considering solidarity and equitable sharing of costs by all citizens and facilities. Various user groups should be made aware of - and be able to identify with concepts such as 'water- and catchment solidarity' (UNEP et al. 2004).

Pollution permits and pollution trading

According to Sawyer et al. (2003), the potential of pollution permits and pollution trading regimes should be explored. To promote sustainable development as the central theme relating to sanitation or wastewater management it is necessary to stress the high economic and social costs of environmental contamination. Pollution permits and pollution trading could help raise awareness on the links between appropriate pricing of environmental goods and services and environmental degradation. (Sawyer et al. 2003)

Modes of payment and fee types

It is important to promote flexible payment structures and service levels for consumers. The poor in peri-urban areas do not generally have steady incomes, and are often unable to pay a monthly bill in a large, lump sum. Research has shown that the poor will pay, but payment needs to reflect the consumer's special circumstances. Hence, it may be useful to allow for the possibility to pay more frequently in smaller amounts, to accommodate household income cycles. Flexible payments can be encouraged both for recurring costs and for capital costs. For example, many projects in developing countries encourage communities to contribute to capital costs not only in cash but also through supplying labour and local materials (Cardone, Fonseca 2003). Neighbourhood groups may be useful in organising collective payments (although there may be problems in group decision making).

Table 16 on the next page shows fee Types, determination bases and possible applications for waste-management and sanitation projects.

Table 16: Fee types, determination bases and possible applications

Basic charges	Flat rates	Scaled flat rates	Volume-based fees	Hybrid systems
Collection of a basic fixed charge that is independent from the actual use of a service	Fees are collected per user (unit) in the form of a unified lump-sum independent from use or consumption	Fees are collected as lump-sums based on linear or progressive tariff scales	Fee collection based on metering volumes disposed of per period (usually per month) and user unit (usually per household) and appropriate tariffs	Combination of basic charges with user-related (normally scaled) flat rates or volume-based fees
Determination bases				
– per connection or subscriber (usually per household or plot)	– per person or household member – per household or apartment – per plot	– persons per household – living area or plot size (m2) – Length of street frontage	– refuse: weight (kg) or volume (m^3 or litres; bins, bags or similar receptacles) – wastewater: volume (m³ or litres) of sludge (latrines / septic tanks) or wastewater (usually based on water consumption)	*same as for scaled flat rates or volume-based fees*
Advantages				
– relatively easy to collect – permits distinctions between fixed costs and volume or consumption based costs – can be based on linear or progressive tariffs	– relatively easy to collect – is like a tax; has no direct relation to the actual utilisation of a service	– relatively easy to collect – enables a certain degree of consumption or utilization related differentiation to be made (e.g. when the number of household members is used as determination base)	– enables utilization related differentiation – provides incentives to reduce wastewater or refuse – possibility of regulating consumption with progressive or scaled tariffs	– enables utilization related differentiation – provides incentives to reduce wastewater or refuse – possibility of regulating consumption with progressive or scaled tariffs
Pre-requisites				
– simple user register or cadastre	– comparable user consumption patterns – simple user register or cadastre	– more differentiated user register or cadastre with additional information on the determination basis used for rate scales	– detailed user register or cadastre with regular identification or metering of volumes disposed of	– detailed user register or cadastre with information according to the determination base applied or with regular identification or metering of volumes disposed of
Possible application(s) in urban poor settlements				
– share of costs or neighbourhood fee for rainwater drainage and erosion control – share of costs for refuse collection in simple drop-off systems; – share of costs for piped sewerage systems	– simple drop-off systems of refuse collection – emptying of latrines and septic tanks – simple piped sewerage systems – rainwater drainage and erosion control	– drop-off and pick-up systems of refuse collection – emptying of latrines and septic tanks – piped sewerage systems – rainwater drainage and erosion control	– refuse collection from individual households or plots in pick-up systems – emptying of latrines and septic tanks – piped sewerage systems	*same as for scaled flat rates or volume-based fees*

Source: (Bockelmann, Samol 2005)

What to do if users don't pay

Non-payment by poor users is perhaps the greatest disincentive to the private sector for provision of services to low-income areas. The following methods that have improved payment collection rates in low-income areas of Buenos Aires are given by Budds (2000):

- small communities: block billing - contract with local residents' association instead of individuals and settlement billed as a whole – has been very successful
- bigger communities – block billing by block or street etc.
- larger areas - distribution of bills by local resident who is paid for distributing bills and collecting and delivering payment as a % of the amount collected – has improved payment rates
- individual initiative e.g. one person goes to the city to pay bills and others pay him/her to take their bills, too. (Budds 2000)

4.6.7 Developing an Effective Financial Management System

Many communities and sometimes also municipalities lack skills in financial management which would allow them to organise, implement and control a cost recovery system in an efficient way. Appropriate financial management capacity and skills are necessary to run a service efficiently. An assessment of the management capacity of the community or local authority managing the system is therefore crucial (Cardone, Fonseca 2003).

The tasks and functions of financial management depend on the complexity of the chosen operational and organisational setup. While some basic requirements generally apply to all operational setups and enterprise types, they will need to be appropriately scaled to the specific conditions and size of different operators. According to Bockelmann and Samol (2005), such generic tasks relate to the following areas:

- budgetary planning and budget management;
- billing and fee collection;
- accounting;
- controlling and monitoring.

Depending on the operational set-up and context, these tasks will have to be further detailed and differentiated. Moreover, appropriate organisational structures with sufficiently qualified personnel will have to be established. If communities have to manage aspects of financing, NGOs can often play a role in the training of financial management tasks.

Key Issues

Sanitation based on drop-and-store, including emptying treatment and reuse, seems to have equal operating costs like Ecosan. The largest contribution to operating costs for Ecosan (and drop-and-store) originates from collection and transport. Urine harvesting is a major challenge as transport and storage costs are high. Full cost recovery for O&M should be pursued as a goal to reach sustainability. User fees should cover direct and support costs of O&M. However, alternative financing sources have to be identified for the case that not all costs can be covered through user fees (very likely in the case of large repairs). There are various means to assess and maximise willingness to pay. Financial responsibilities in multi-stakeholder approaches have to be assigned and sealed in an agreement or contract. Governments and NGOs normally pay for training and support activities in community-managed projects. O&M costs need to be identified. They are difficult to determine- and various ways of costing exist. O&M costs can be minimised by various means. Tariffs have to be set assuring equity and full-cost pricing. Targeted subsidies may be necessary for poor people. A flexible payment structure is needed to reflect customers' special circumstances. Various fee types for different applications exist. Finally an effective financial management has to be developed.

4.7 Alternative Financial Sources

It is important to plan and decide on financial mechanisms that would cover costs, if these cannot be covered by user's fees. This should apply primarily to pay for big repairs or replacements to and with certain qualifications and usually on a temporary basis for operational costs also. Sources include having access to credit facilities, establishing a fund, subsidies, and cost-sharing arrangements with the authorities. Table 18 on the next page summarises various alternative financing mechanisms (other then tariffs and rates):

Access to various financial sources depends on the local context. In some countries or regions for example the private-sector may play an important role while elsewhere national government is the main source for finances. Table 17 shows the country-specific share of expenditures in WSS in Ethiopia, Kenya and South-Africa. The significant differences in the channels and sources of finance available in each country reflect in large measure the prevailing institutional arrangements[40].

Table 17: Expenditure estimates for different levels and service providers

	National/ Federal Govt.+ National Utility			Local Govt. + Local Utility			Non-Government			Total WSS
	Federal	Utility	Total	Local	Utility	Total	CBOs	PSSPs	Total	Expenditure
Ethiopia										
Recurrent	5.1%	-	5.1%	-	66.1%	66.1%	28.8%	-	28.8%	38.0%
Development	3.2%	-	3.2%	-	33.1%	33.1%	63.7%	-	63.7%	62.0%
Total	**3.9%**	**-**	**3.9%**	**-**	**45.6%**	**45.6%**	**50.5%**	**-**	**50.5%**	**100.0%**
Kenya										
Recurrent	29.9%	20.7%	50.6%	29.0%	5.4%	34.4%	10.7%	4.3%	15.0%	56.2%
Development	29.1%	9.4%	38.5%	8.8%	1.1%	9.9%	51.2%	0.4%	51.6%	43.8%
Total	**29.6%**	**15.8%**	**45.3%**	**20.1%**	**3.5%**	**23.7%**	**28.4%**	**2.6%**	**31.0%**	**100.0%**
South Africa										
Recurrent	4.3%	2.3%	6.7%	83.6%	8.6%	92.2%	0.4%	0.8%	1.1%	78.9%
Development	-	1.7%	1.7%	97.3%	-	97.3%	0.2%	0.7%	0.9%	21.1%
Total	**3.4%**	**2.2%**	**5.6%**	**86.5%**	**6.8%**	**93.3%**	**0.3%**	**0.8%**	**1.1%**	**100.0%**

Adapted from: (WSP-AF 2003)

Vast differences in the financial capacity of the countries and varying percentage of Gross Domestic Product spent on WSS are characteristics of Sub-Saharan Africa and will greatly influence the accessibility of financial resources. However, weak and opaque budgeting and accounting procedures in most Sub-Saharan countries make rigorous comparative evaluation of resource flows difficult and often incomparable (WSP-AF 2003).

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40 For information on country-specific financial/ institutional environments see: (WSP-AF 2003)

Table 18: Alternative financing mechanisms other than tariffs and rates

Finances within communities
Voluntary funds Found in communities with seasonal income and a tradition for fund-raising to help construction and big repairs. People can contribute according to their ability to pay, but the contributions are difficult to control. **General community revenue** Found in communities with their own sources of income, which pays for construction and extensions. There may be disputes on the priorities in utilising these resources. **Revolving funds** Starting capital may come from a government donation or by the issue of shares to individual households. On the basis of this capital, loans are given to individual households or groups. Upon repayment, new loans are given to other members or groups.
Private or cooperative funds
Cooperative funds Sanitation is initiated and financed through a production cooperative or village revolving fund, which pays for construction and expansion. **Private sector involvement** The private sector can invest some of its own capital in a sanitation scheme. However, it will look for something in return which can justify its investment, such as future contracts or ownership.
Subsidies from local/national government
Taxation (municipal resources) Municipalities can collect the necessary funds through local taxes. Payment can be linked to income level. This option presents limited scope for community involvement in decision-making and financial system management. **Cross-subsidy** One way to make the service equitable and affordable for all is to subsidise the poor by imposing surcharges on high-income consumers. Another example of a cross-subsidy is between sectors within the same community or municipality. **Government subsidies** The central government and local authorities allocate part of their budget to O&M activities. Subsidies can also be given to reduce the price of spare parts and chemicals, and to make technical personnel available free to communities on request.
Credit - loan mechanisms
Loan through a bank A bank allocates a loan to a User Committee. However, many banks have a poor small credit policy. Communities cannot always produce the necessary guarantees. **Micro-credit schemes** Communities organise, through local associations, micro-credit schemes where individuals and groups can borrow money with a predetermined and agreed rate of interest. These schemes are adapted to community needs and realities, but there is a limit to their lending capacity. **Social and development funds** Many developing countries have created special funds which give access to money for social and development purposes, with an interest rate which can be much lower than that in the financial market. However, access to these funds is open only to local authorities and municipalities, and not necessarily to communities. It is therefore important that communities and municipalities work in partnership. Access to these funds can be eased through the payment of a regular fee, which will provide the possibility of obtaining a loan in case of necessity.
Grants
Donations (twin villages) Donations can come through individuals (former inhabitants of a village who now live in a city or abroad). In some cases, villages are twinned with other villages and cities in other countries, and grants have been allocated through this mechanism in the past.

Adapted from: (Brikké 2000)

According to Cardone and Fonseca (2006), a lack of information on alternative financing resources constraints the dissemination and wide-spread use of innovative financing mechanisms in the water and sanitation sector. While there has been a lot of activity in recent years within the donor community to create new initiatives and programmes to support domestic private sector initiatives and innovative finance approaches, there is limited awareness and understanding at international, country or regional level about these activities. A recent study found that in several countries, including Mozambique, Kenya, Uganda, Ghana and Senegal, only a very select few outside the international development community know about the different programmes working to develop innovations, nor did they know of different finance instruments available. Even some bilateral donors expressed a lack of awareness. There is obviously an information and dissemination gap between the financial and the water and sanitation sectors. In the now following chapters some alternative financial sources will be presented.

4.7.1 External Donor Funding

According to Bockelmann and Samol (2005), sanitation initiatives/projects in urban poor settlements are often financed by external bi- or multilateral governmental and nongovernmental donor agencies, through grants or loans at favourable conditions. In most cases, donor support is provided for specific projects at specific locations, or in the context of broader, countrywide support programmes, often in combination with national contributions or financial resources. Grants or loans with favourable interest rates are mainly provided to finance investment costs or complementary advisory assistance services (e.g. for community mobilisation, participatory planning, organisational development, etc.). Bockelmann and Samol (2005) further state that in contrast, operating costs are usually only subsidised by external donor funding in exceptional cases, and on a temporary basis, e.g. to build up initial operational structures or for urgently required maintenance work. Long-term operations are usually handed over to an operator as early as possible, usually with the stipulation that operating costs are to be covered from user fees. External donor grants or loans are often provided in order to demonstrate how investment costs can be financed and how sustainable financing concepts can be established.

It has to be kept in mind that donors usually want to have a ‘visible’ outcome when they provide financial resources - they rather tend to spend their money for the installation of new facilities than for the O&M of already existing hardware and infrastructure. One could say: ‘A new toilet-block is more prestigious than maintaining several already existing ones for the same amount of money.’

4.7.2 Subsidies

Municipal or governmental subsidies are a possibility for financing the investment and operating costs of sanitation services. They can either come from the regular budgets of institutions responsible for sanitation services, or from special support programmes or funding facilities (often supplied or co-financed by loans or grants from external donors). Regular public budgets are generally limited and funding is often only made available for urgently needed maintenance or repair work. Furthermore, governmental or municipal budget funding is often used to finance operating costs, primarily the personnel costs of public service operators who rarely collect cost-recovering fees. Special public support programmes or funding facilities are usually available to only finance project-specific investments (Bockelmann, Samol 2005).

It has been said before, that fees should be set to recover the running costs of a programme. As the poor often do not benefit from increased coverage and existing WSS services, available subsidies should be used to help the poor to get access to financial resources and subsequently to improved services. Mehta (2003) identifies three sets of pro-poor subsidies:

- Use of access subsidies for either water or sanitation, as well as for demand promotion and hygiene awareness, either given directly to consumers or through the service providers.
- Improving the cross-subsidies used throughout the world, through specific principles and rules to provide subsidies for access and/or service payment.
- The more recent use of incentive-linked subsides within an output-based aid framework, including direct subsidies for access or consumption to consumers, minimum subsidy concessions targeted to reach the poor, and support to pro-poor reforms

Access subsidies, especially hardware subsidies, have to be applied with care. Subsidy approaches must avoid distorting decision-making to the extent that wrong choices are made. In a review of Ecosan experience in East and South Africa (WSP-AF 2005), most of the projects described have used some form of subsidy to promote or support widespread use of new technologies. Most of these subsidies have been so large as to be unsustainable for a regional or national programme. In some cases the subsidy has even persuaded people to consider a technology that they are not even sure they like. Nonetheless, it is likely that urban and peri-urban collection services for surplus Ecosan domestic by-products would have to be subsidised at the initial phase, just as wastewater treatment plants generally are (Sarar Transformación SC 2006).

Cross-subsidies are known from the water-supply sector mainly. Service providers in developing countries typically use some form of subsidies for water, generally to help the poor gain access to services. One of the most common modalities for this is the use of cross-subsidies through setting different prices for different consumer categories. To learn more about advantages, disadvantages and the sustainable use of cross-subsidies refer to: Mehta (2003)

Traditional subsidies often lack any close correlation with the actual services delivered. This generally resulted in a lack of transparency, poor or adverse incentives for the service providers, and limited opportunities for leveraging the limited public funding through private or community resources (Mehta 2003). A relatively new concept of subsidies are **incentive-linked subsides.** These recent mechanisms are generally referred to as **output-based aid**. They seek to address these weaknesses by delegating service delivery to a third party (such as a private company or NGO) under contracts that link the payment of subsidies to the outputs or results actually delivered to target beneficiaries. The concept of output-based aid applies to any infrastructure or sector, and examples of its use are available in most sectors in different countries. Output-based-aid is used to structure PPPs in a more sustainable way (see chapter 4.7.5: Public-Private-Partnerships)

Changes in political or economic conditions, like the changes of political majorities following elections, or a decline in tax revenue, can affect the continuity of subsidies from the government or municipality and their longer-term availability. According to Bockelmann and Samol (2005), these subsidies are therefore not a reliable form of financing, and should be included in financial and operational concepts only in exceptional cases.

4.7.3 Community Resources

According to Bockelmann and Samol (2005), contributions by the community can, in principal, be financial and/or in the form of self-help or mutual help, e.g. in the construction of facilities or for other works. Furthermore, operating costs can be reduced by user self-help or mutual help contributions, e.g. in maintenance and repair, or in the collection and administration of fees. According to the authors, the following aspects will need to be considered:

- One-time payments to finance investment costs can exceed a household's monthly income, and thus require a loan (see also 4.7.4 Micro Finance). In such cases, loan repayment can mean that a considerable financial burden has to be shouldered in addition to the payment of user fees. If this exceeds the target group's financial capacity, it usually indicates that the technical standards used are unaffordable.
- Self-help or mutual aid in the construction of installations can also be a serious problem for poor target groups, as the time and energy needed may impinge on the possibilities of working for direly needed income. Moreover, additional efforts and inputs may be necessary to organise and coordinate self-help activities, and to ensure appropriate quality standards.
- Self-help in operations can similarly put additional strains on poor users in their daily struggle for survival, and thus is not be applicable or favourable in all cases. It also usually requires stable organisational structures with long-term perspectives.

Apart from a one time financial contribution for a household or plot related investment (toilet etc.) communal funds can represent adequate financial contribution mechanisms (see also next chapter: Micro Finance). Financing systems used in water supply projects may be adapted to resource-oriented sanitation. Common communal fund financing options used in community-based water supply projects are illustrated in Table 19. However, according to Anschütz (1996), the applicability of these systems to solid waste management projects in low-income urban areas is sometimes problematic. Voluntary funds often do not function adequately in solid waste management projects, as some examples from Indonesia show. Other communal funds will probably encounter specific difficulties in cities, because they require a communal production base which may not exist.

Table 19: Community options for cost recovery in water-supply

What?	Voluntary funds	General community revenue	Cooperative funds
When?	In communities with a tradition of fund-raising, seasonal income, and a good knowledge and control of payments according to household capacity and benefits.	In communities with own sources of income and a water supply with public facilities.	Water supply initiated and financed through production cooperative or village revolving fund; no direct payments for water used.
What for?	Financial contributions to construction; occasional larger contributions to maintenance and repair of simple systems with public water points.	Annual maintenance and repair, financial contributions to construction; depreciation and expansion where possible.	Annual maintenance and repairs; repayment of construction loan; depreciation and expansion where possible.
Who organises?	Traditional leadership, voluntary organisations, e.g. women's groups, tap organizations.	Local government, community water committee or subcommittee.	Cooperative's executive committee, community water committee or subcommittee.
How?	Targets are set and funds collected periodically through meetings, house-to-house collections, bazaars, etc. Funds are collected in advance or when required.	Reservation of funds based on the estimated costs and net annual income of the community; cost-reduction or income generation where necessary.	Reservation of funds based on estimated costs and income from cooperative ventures and/or member fees; cost-reduction and/or member fees; cost-reduction or income generation where necessary.

Source: (Evans 1992)

4.7.4 Micro Finance

"Microfinance means literally that the amount of finance provided is small. It has been defined as the provision of diverse financial services to low-income people." (IRC 2006). However, there is no single agreed definition of the term, and so it can mean anything from community based revolving funds to the products offered by affluent banks to specific clients. Normally, the term 'microfinance' is used in the context of micro-credits. According to Cardone and Fonseca (2003), micro-credit involves lending mechanisms that are similar to credits given by banks, except that they differ in their scope. Micro-credits are generally small in volume and respond directly to the specific needs of rural or low-income urban individuals. It is possible to distinguish three types of micro-credit:

- Micro-credit through a bank;

- Micro-credit through an association;
- Micro-credit through individuals.

The success of the microfinance approach in supporting informal micro-enterprises in low-income countries has led to it being considered in other areas of development. For example, the use of microfinance intermediaries to supply the credit needed to implement water and sanitation services has become a promising approach to improving service coverage in low income communities (Saywell 2006). In general, micro-credit systems can overcome financial obstacles and promote development in areas that are beyond the reach of the conventional banking system. They offer marginal groups within a community a possible access to finance for small, income-generating activities. For major investments, communities still need to secure finance from banks or development funds. Micro finance can be especially attractive for the implementation of small-scale sanitation systems (Sawyer et al. 2003). Potential clients of microfinance for sanitation or related services include small scale private providers and households. Microfinance has been used for the construction of household latrines and public toilets, for manual latrine-cleaning services and suction trucks which are used to empty pit latrines (Saywell 2006).

The challenges and constraints faced by the poor in lending can be overcome through strategic partnerships with local non- governmental organisations and the private sector (Cardone, Fonseca 2003). However, a long term repayment period is normally required and in some cases there is no direct link with income generation (IRC 2006). Often the conditions required to access loans make it difficult for individuals to get loans for water and sanitation activities. A group loan to a committee makes access easier. Two factors contributing to the success of a community sanitation project in Senegal were: the use of low cost technologies such as Ecosan, and the link between the sanitation fund and urban agriculture to make it more attractive to the microfinance institution (Malick, Enda Tiers Monde 2006). For a sanitation project a micro-credit system could be used to (Cardone, Fonseca 2003):

- Contribute to investments;
- Purchase material and equipment for replacement, extension and rehabilitation;
- Finance major unforeseen repairs;
- Cover short-term cash-flow problems;
- Develop a stock of spares, parts and tools.

In Sub-Saharan Africa the microfinance sector which is yet less developed, than for example in Asia or South America, though greater outreach and viability is possible in some countries. Microfinance in Sub-Saharan Africa is still relatively young. The majority of microfinance institutions (MFIs) in the region are still in the start-up and/or consolidation phase and are grappling with capacity, outreach, and viability issues. However, there are some exceptions, as experiences from Kenya illustrate (Mehta, Virjee

2003). Successful examples (and one not successful example) for microfinance in sanitation in Africa are also given by Saywell (2006).

Microfinance can either be used for household sanitation investments or for starting up or scaling up sanitation services through either CBOs or through the private (small scale) sector:

Microfinance for household sanitation investments

In most sanitation-related programmes the emphasis is shifting away from any household subsidies. The cost of a toilet/latrine is likely to range from about US$ 15 to 150 in different countries in the region, according to the type of technology used and rural/urban location. These are very big investments for most poor households, and access to credit would enable more households to install such facilities. However, such efforts require support from the government and other stakeholders (like NGOs) for demand promotion and adequate technical support in order to provide cost-effective solutions and quality control.

Factors affecting potential opportunities

- Generally not recognised in most publicly funded programmes as an appropriate option
- Potentially large market in rural CBO-based schemes, but dependent on a programme and technical support
- Needs to be linked to a demand promotion programme as well as appropriate technical support
- Potentially large market

Types of risks

- More amenable to microfinance lending due to the individual borrower
- For urban utility, the main problem is willingness to provide services to the low-income customers in informal settlements due to the legal tenure issues
- Lack of easily perceived financial returns or savings for the household, making publicly funded demand promotion critical (Mehta, Virjee 2003)

Microfinance for community managed projects

For ongoing community managed schemes two possibilities for microfinance could be of interest:

- financial services to collect/deposit user charges and possible credit for repairs and expansion/augmentation of ongoing CBO schemes that are already collecting user charges; and
- financial services for new CBO schemes in the form of management of capital grants and later collection and deposit of user charges, leading to credit after a pe-

riod of about two years. In the second case, a link up with the project/programme financier may be essential.

Factors affecting potential opportunities

- Larger community contributions are crowded out by the design of subsidy policies: especially relevant for high-cost schemes providing higher level of services
- Potentially large market in Africa with the emphasis on decentralisation and demand responsive approaches
- In transfer of schemes, likely problem of lack of incentives for CBOs to participate

Types of risks

- Risk of new CBO without any credit or cash-flow history
- In some cases, lack of a clear legal status of the CBO is likely to be a problem
- In ongoing schemes, past cash-flow history through user charges can be assessed. Also, the risk is lowered, or can be better assessed, as the MFI establishes a relationship and cash flow history with the CBO
- In new schemes or transfer of schemes, close coordination required with government/NGOs/donor programmes (Mehta, Virjee 2003)

Microfinance for sanitation service providers

Most service providers meet their working capital requirements through user charges. However, the lack of access to credit for capital investments is often one of the main constraints to new entry and expansion of service by small providers. Thus, potential demand for finance from different types of private service providers is mainly for capital investments, either at entry level or for expansion. There is a wide variation in investment levels, depending upon the level of technology. Manual latrine cleaners, for example, invest only US$20–50, which represents between 1 and 6 percent of annual revenue for those businesses. Suction tanker businesses require large capital investment, which represents up to 90 percent of annual revenue. In most cases the providers rely on their own savings and borrowings from friends and relatives.

Factors affecting potential opportunities

- For emerging systems in small towns potential private investments are often crowded out: use of minimum subsidy concessions may be useful
- High cost and short tenor of conventional microfinance products poses a constraint, as infrastructure lending requires
- medium- to long-term tenor

Types of risks

- For PSSPs in urban informal settlements, lack of a firm legal basis and regulatory framework poses a significant risk (Mehta, Virjee 2003)

4.7.5 Public-Private-Partnerships

Private sector involvement should not be expected to substitute public investments nor lead to a decrease in the responsibilities of governments. In general, the private sector is likely to be able to make its best contribution, help reduce costs and improve standards if (Sawyer et al. 2003):

- it is given long term, flexible contracts for large areas and wide ranges of services;
- and if the contract specifies services outputs to be delivered rather than tying it down with detailed specification of capital works.

The use of outcome-based arrangements will encourage the private sector partners to use least costly solutions to problems ('output-based-aid'; see chapter 4.7.2: Subsidies).

Under private sector management, utilities seek to recover their full costs, and in addition generate a surplus profit for the provider. There is a need to distinguish between capital and O&M costs, as normally not all costs are recoverable. Recoverable costs may include capital and O&M costs (also debts and interest), but the cost of these should be expected to be spread over the life of the contract. Local governments should ensure private providers a reasonable flow of funds in order that the operator can make a profit without immediately raising charges to high levels in order to recoup costs. What governments need to consider at the pre-bidding stage is how tariffs can be structured to benefit low-income groups and how institutional responsibility will be allocated for this task. Tariff structure often changes under PPP arrangements to reflect the cessation of government subsidies and full cost recovery. However, if tariffs rise several-fold under private-sector management, this will have a negative effect on low-income people. Although tariff structures designed to benefit low-income people can be useful, many authors argue that these do not benefit the poorest people, who usually lack access to the service anyway and therefore get no benefit. Some believe that it is better to achieve social objectives through competitively neutral mechanisms like subsidies and general taxation rather than reduced tariffs. (Budds 2000)

<u>PPP for the Poor</u>

The target of a PPP should be to provide better services, but also to expand services to areas where they are needed most. Thus, the development of a strategy towards benefiting the poor has to be developed within a PPP agreement. Poor areas are generally seen as problematic by private companies, as cost-recovery can become difficult.

Sohail (2003) provides guidelines for pro-poor PPP arrangements which are intended to provide "straightforward assistance to everyone involved in the field." (Sohail 2003). In the development of a private-public partnership typical phases can be found (beginning with the assessment of the current situation and normally ending with the renegotiation or termination of the contractual agreement). The guidelines document refers to these different phases of the PPP process and gives for each phase lessons to learn and development of checklists, to ensure pro-poor arrangements are regarded. Figure

26 summarises the process and hints at some activities the author envisages for pro-poor PPP.

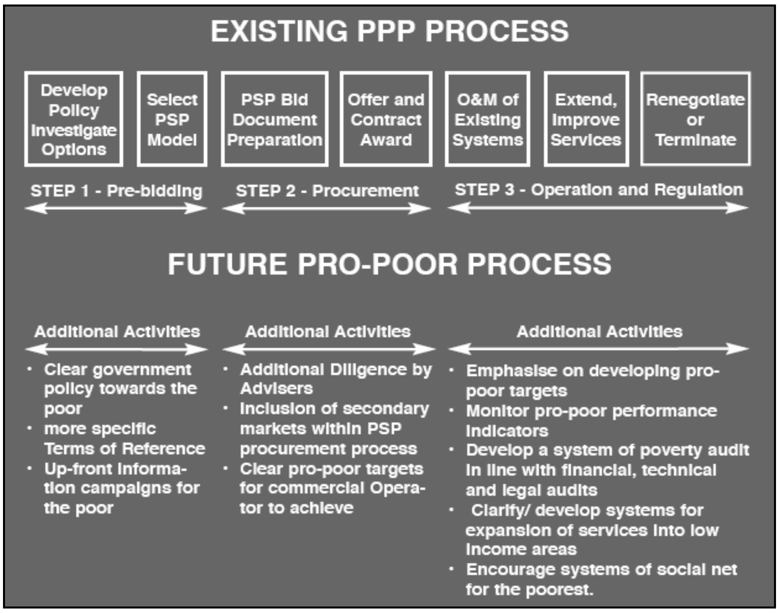

Figure 26: Existing PPP Process and Future Pro-Poor Process (Sohail 2003)

The risk of loss of revenue from providing sanitation services to low-income settlements can act as discouragement to private sector. It is therefore beneficial for governments, wishing to engage in private-sector participation to extend water and sanitation services to low-income settlements, to define the financial arrangements to apply to such contracts at the bidding stage, in order not to discourage the private sector from bidding. The need for alternative financial arrangements for low-income areas arises from the fact that the private sector fears that it will be unable to recoup the costs of provision through lack of service payment. Whether or not this view is founded, alternative arrangements are being implemented in low-income areas to mitigate this risk. (Sohail 2003)

Now following is a short introduction to a guideline for the financial structuring of private-partnership-projects in the water and sanitation sector. Several different types of risk mitigation tools and modalities are described in the source document (Vives et al. 2006) and a methodology to find the best modality for PPP investments in infrastructure projects[41] is proposed. In this publication most of the alternative financial sources and mechanisms, presented before, are also described and supposed to be available for structuring PPPs:

[41] Here 'Investments in infrastructure' does not only relate to the capital investment but also to responsibilities for O&M, commercial risk and asset ownership.

Financial structuring of infrastructure projects in PPPs

According to Vives et al. (2006), a great number of failures in investments in infrastructure, particularly in water and sanitation, can be attributed to the application of financial structures, mostly imported from other environments, without paying due attention to the local conditions. Vives et al. (2006) present an analytical framework (Figure 27) which considers the feasibility of different modalities in PPPs, given the prevailing, or likely to prevail, local conditions and classifies them as being feasible, non-feasible or feasible only with enhancements or risk mitigants (available tools).

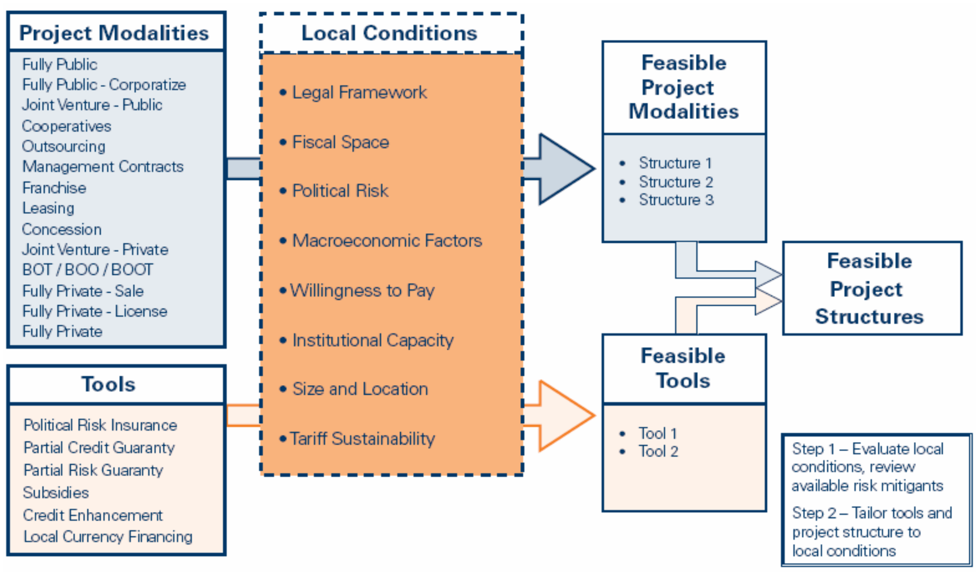

Figure 27: Analytical framework for the financial structuring of PPP infrastructure investments (Vives et al. 2006)

Figure 28 outlines how the framework components described in Figure 27 can be used to evaluate the potential viability of various project structures for a given PPP opportunity. As the synthesising tool for this assessment the project feasibility map in Figure 28 shows the analytical process that should be followed in four steps:

A. Assess Local Conditions

The analysis begins with an assessment of the local conditions/variables. A variable ranked as low (or weak) indicates that there are higher risks to a project. Higher risks associated with low local conditions ratings limit the number of feasible project structures possible. In general, with strong local conditions, greater private participation is possible as risks to investors and lenders tend to be lower. A strong capacity to enforce contracts, for instance, makes most of the tools for risk mitigation effective, and hence allows a broader range of project structures that can be arranged to suit the local conditions. With weak local conditions, private participation options will tend to fall into the type of self-enforcing agreements.

B. Evaluate Which Modalities May Work

After the initial assessment of the variables, project modalities need to be considered. While an investor or government may have a specific project modality in mind (for example, a concession), not all modalities will work successfully where there are weak local conditions.

C. Assess Which Tools May Apply

The application of risk mitigation tools may enable options for private investment that would not otherwise exist. The range of risk mitigation tools generally available and how they enhance project feasibility is described in Vives et al. (2006). Each project will require its own assessment of available tools and how they may enhance project feasibility.

D. Combine Tools and Modalities to Determine Potentially Feasible Project Structures

With the identification of weak local conditions, the evaluation of possible modalities and the review of available risk mitigation instruments, it is possible to construct the project feasibility map.

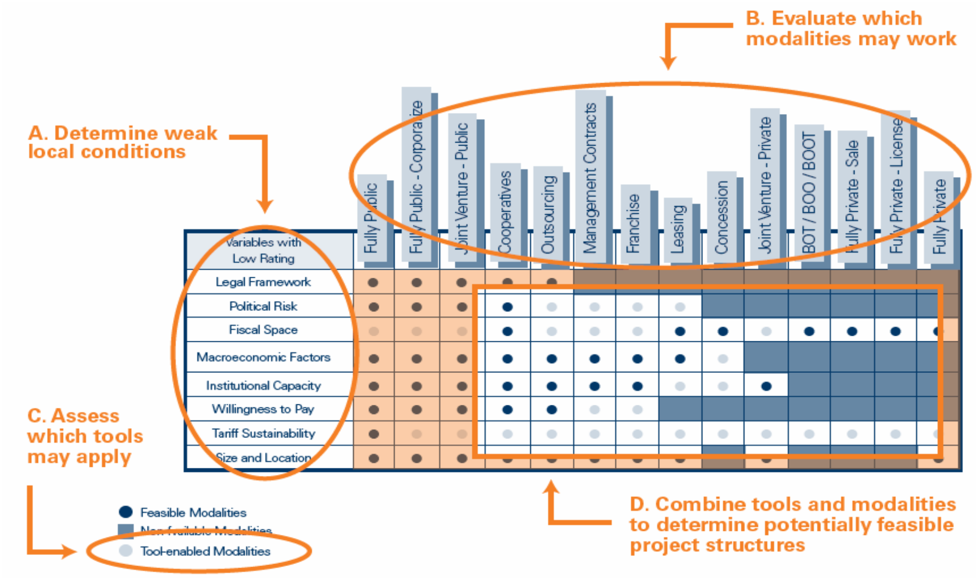

Figure 28: Project feasibility map - analytical process (Vives et al. 2006)

This short-run, ‘static analysis’ is important for understanding how to incorporate the three components of the analytical framework (local conditions, tools for project enhancement and project modalities). However, it is also important to consider the dynamic evolution of local conditions as they improve or deteriorate in the medium term, creating evolving conditions for project success. A dynamic analysis can illustrate the effects of changing a variable with a low rating to one with a high rating. As local conditions improve in this fashion, more tools and structures become available. (Vives et al. 2006)

4.7.6 Innovative Money-Flow Model

As already discussed, the private sector already plays a major role in FSM in many African cities. However, some major problems are hampering the sustainability of the services:

- FS mostly gets dumped indiscriminately at the city boundary without further treatment. Treatment plants need money to build and operate and the revenues from biosolids sale would not recover the costs.
- Emptying fees are too high for many of the poor.

To address these problems, innovative money-flow models for sustainable FSM have been developed by Steiner et al. (2003). These money-flow models represent a good example for the use of several financial mechanisms, described before, to ensure equitable and sustainable cost recovery. The authors decided to subdivide their models into two main groups: without and with financial government intervention (e.g. subsidies). To develop the various money flow models, several assumptions had to be made by the authors. These assumptions are based on a sludge treatment scheme in Ghana. Selected money flow models have been tested, each presenting benefits and drawbacks. An ideal case would probably be a combination of several incentive measures and subsidies by the responsible authority. This 'ideal' financial model solves the problems described above and at the same time assures cost recovery.

Table 20 contains main reflections derived from the developed money flow options, and provides useful inputs for financing. Figure 29 completes the model graphically.

Table 20: Money flow solutions to current faecal sludge management problems

Current problem	Possible solution approach	Expected impact
High pit emptying fees	– Reduction of the emptying fee by remunerating the collection company when delivering FS to the treatment plant	– Pit emptying becomes affordable for everyone – Emptying company is forced to deliver to the FS treatment plant to be profitable
Indiscriminate dumping of untreated FS	– Implementation of an FS dumping remuneration on the treatment plant or official FS dumping site – Control of emptying companies by the authority (e.g. via a licensing process)	– Incentive measure to get the FS where you want it – Possibility to control and penalise collection operators – Contribution to the FS treatment costs
FS treatment requires external funds	– Implementation of a sanitation or similar tax (e.g. a surcharge on the water supply bill)	– Sustainable financing of FS treatment (capital and O&M costs)

Source: (Steiner et al. 2003)

According to the authors, FS delivery remuneration should be set at an attractive level for collection operators to convey the sludge to the treatment plant and to reduce pit emptying fees, but low enough to prevent abuses. The dumping remuneration level will depend on local conditions. It may not be necessary everywhere, as some cities use collection companies to dispose of the FS at an official site controlled by the municipality.

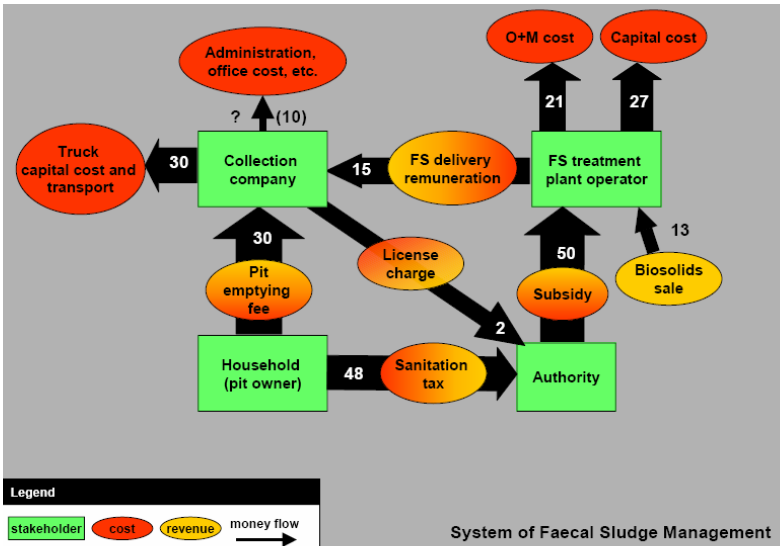

Figure 29: Innovative money-flow model for faecal sludge management (Steiner et al. 2003)

Key Issues

Many different alternative financing mechanisms exist, but access to these sources depends on the local (country specific) context. Donor funding goes normally to hardware rather than O&M. Different subsidy types can be used to help the poor getting access to financial resources. Communities can contribute by financial means or by self-help or mutual help – e.g. in maintenance and repair or in the collection of fees. Several types of community funds are known and used in water-supply projects – they may be adapted to sanitation. Micro-credits are young and not yet widespread in Africa – exception: Kenya. They can represent a chance for communities and private entrepreneurs to start or extend service provision. PPPs will not substitute public investments but they can help reduce cost and improve standards. PPPs have to be 'pro-poor' to provide services to all. Guidelines and tools for financial structuring of PPPs are available. Innovative money-flow models for FS management have been developed and may represent good examples for designing a sustainable cost-recovery system for resource-oriented sanitation.

5 Case Study

5.1 Introduction

From April 16th to April 26th 2007, a case study in Nakuru, Kenya - one of the consortium members of the ROSA project - was conducted. Nakuru was chosen for this study as it is one of the two project partners of Ecosan Club Austria and furthermore because Nakuru is very active in the field of community empowerment and environmental activism. Local CBOs, NGOs, the local university (Egerton University), the municipality of Nakuru (MCN) and other stakeholders have formed an environmental consortium to join forces and address (i) solid waste management, (ii) catchment conservation, (iii) and water and sanitation problems. This consortium is coordinated by the NGO Practical Action, which is very active in Nakuru, in the fields of community support, training and environmental issues.

Target of the research was:

- To find out about the composting activities which take place in Nakuru. The possibility of co-composting of organic waste and human excreta should be explored.
- Assessment of the partnerships in O&M and the main problems/constraints for O&M of existing services in Nakuru.

Several points of interest were visited, among these:

- a CBO managed composting plant;
- an organic fertiliser manufacture;
- the peri-urban areas;
- the municipal vehicle-depot.

A semi-structured interview with a municipal officer of the health department was conducted, and furthermore, local ROSA team members could answer many questions. Due to the limited time scale, the performance of a detailed case study was not possible. Hence, the aim of the site visits and interviews was to get a general idea of the situation, rather than to get in-depth information on certain issues. In contrary to the literature survey, which is focussed on human excreta reuse, the assessment of the O&M arrangements and problems in Nakuru is focussed on solid waste management. This is due to the following reasons:

- solid-waste is seen as a valuable resource in Nakuru and a lot of recycling happens;
- human excreta reuse is not practised in Nakuru.

Hence, arrangements in solid-waste management reflect better the possible arrangements for resource-oriented sanitation than local excreta management would do.

5.1.1 Background Information on Nakuru Town

"Once known for its flamingos and dubbed 'the cleanest town in East-Africa', Nakuru has lost much of its past glory." (Practical Action 2005)

Nakuru (see Figure 30) is the fourth largest town in Kenya. It is located 160 km north-west of the capital city of Nairobi and situated in the Rift Valley, along the railway and trunk road. Nakuru lies at an altitude of 1860 metres above sea level and covers an area of 290 km². From this area Lake Nakuru National Park takes up 188 km², leaving 102 km² to the town. The town gained its status as municipality in 1952. Nakuru started from a railway outpost in around 1900 and has rapidly grown since Kenya's independence in 1963. (Practical Action 2005)

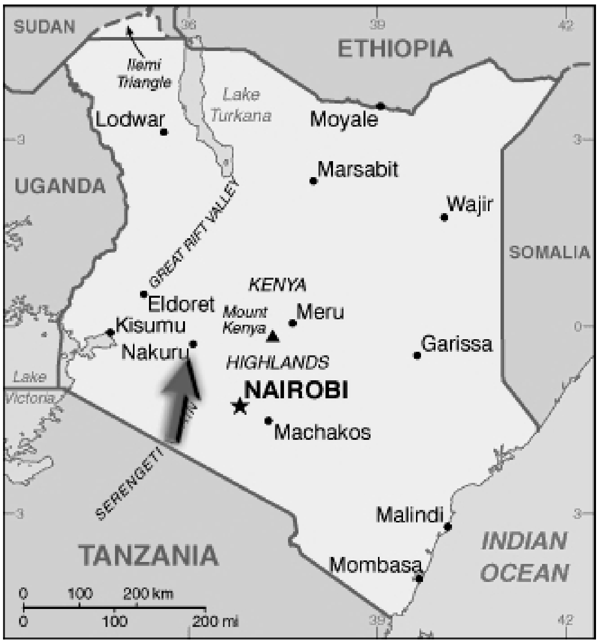

Figure 30: Nakuru in the national context [42]

Nakuru's spatial development is constrained by natural factors. The town is sandwiched between Menengai crater and its associated volcanic landscapes to the north, and Lake Nakuru to the south. Nakuru had slightly more than 300,000 inhabitants in the year 2000 (Post, Mwangi 2006), who are from diverse ethnic backgrounds, languages, religion and customs (Kinyanjui, Mbutura 2004). The population has been growing at a dramatic rate of 5.6% per annum, leading to a projected size of 760,000 by 2015 (Post, Mwangi 2006). The current population is estimated at close to 500,000 persons. The population growth has been influenced by birth rates, rural-urban migration and boundary extensions (Kinyanjui, Mbutura 2004). Growth is predominantly occurring in the outskirts, especially in a westward direction. Here, agricultural land is rapidly being subdivided to accommodate new city dwellers (Post, Mwangi 2006). A

[42] Adapted from: https://www.cia.gov/library/publications/the-world-factbook/geos/ke.html

huge proportion of the population is concentrated in the low-income settlements (peri-urban areas) around Kwaronda, Kaptembwo, Mwariki, Lakeview, Bondeni, Kivumbini and Lanet/Free area (Kinyanjui, Mbutura 2004).

Apparently, most of the growth is unplanned and residents are not served with municipal services. The Municipal Council of Nakuru faces major challenges in improving urban livelihoods due to its weak revenue base. Nakuru suffers, for example, from a serious water supply deficit, running up to more than half the projected demand (Post, Mwangi 2006). Limited employment opportunities furthermore lead to urban poverty (Kinyanjui, Mbutura 2004). Lake Nakuru, a tourist income earner of 20'000 visitors per month is at risk due to plastic waste from town, and leakage from pit latrines and soak-pits (Langergraber 2005). The main environmental concerns result from the interrelation between Lake Nakuru ecosystem, the sprawling human settlements and industrial pollution.

As the quality of the urban environment is steadily deteriorating, citizen associations have started numerous initiatives to improve the level of services, partly in an attempt to create additional employment opportunities. Simultaneously, the informal private sector has stepped in to provide services to the ones that can afford to pay commercial prices. However, citizen’s involvement in projects to establish or improve public services in their areas has suffered various drawbacks. A topical study (Post, Mwangi 2006) has even come to the conclusion that levels of community action in services upgrading in Nakuru are quite low these days.

5.2 Nakuru Waste Composting

In Nakuru organic waste is composted at one larger composting-plant, situated at the dump-site, and at several ‘satellite composters’ scattered in the peri-urban areas. Compost is bought by a local fertiliser manufacture, where it gets processed and upgraded to organic fertiliser quality. The Nakuru composting scheme is managed by a cooperative[43] known as Nakuru Waste Collectors and Recyclers Management (NAWACOM). NAWACOM was initially founded as a CBO, constituting people who earn their living by retrieving reusable materials from solid waste. During time NAWACOM became one of the biggest CBOs in Nakuru. Several smaller CBOs are amongst its members, thus NAWACOM can be called an umbrella CBO. However, they now changed the status to an investment cooperative society where affiliated CBOs can own shares in the cooperative. The umbrella CBO still exists and only part of its members are now shareholders at the cooperative society. The cooperative had 96 members at the time the case-study was conducted, while the CBO had 336 members. To become a member in the

[43] “A cooperative is an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly-owned and democratically-controlled enterprise.” (Ruiz-Mier, van Ginneken 2006)

cooperative, one has to buy 100 shares at 5 Kenya Shillings (Ksh) (500 Ksh =5.54 €[44]) each. Rewards from waste recycling activities are subdivided to the corporation's members according to their shareholding.

5.2.1 Composting Plant at Nakuru Dump Site

On April 16th 2007, the Nakuru dumpsite was visited in order to have a look at the composting plant which has been established there. The open dump-site (called 'gioto') is situated just outside of town in the north-west. The composting is done by Menengai Waste Recyclers Management (MEWAREMA) a CBO at the expansive Nakuru dumpsite. MEWAREMA was started in March 2004 and currently has 50 active members made up of people who derive their livelihoods from the dump site. The group members also live here, some of them already for more than 20 years.

A short non-structured interview was conducted with Mr. Kamau a secretary to the MEWAREMA group (see Figure 31 - Mr. Kamau is on the right side). A local ROSA team member (left on Figure 31) assisted as an interpreter to translate more complex facts from Swahili to English and vice versa.

Figure 31: Interview at the composting plant

The composting process was described as follows:

- MEWAREMA members collect organic waste from the dump site;

[44] Currencies have been converted on: http://www.xe.com/ucc/convert.cgi [accessed on 20.05.2007]

- only market and farm wastes are composted; for market wastes some sorting is done to remove impurities;
- windrow composting is used;
- banana fibres are placed at the bottom and also used to cover the heap
- the water-content is maintained by 40% by continuous addition of water;
- turning of waste is done every 3-4 days depending on the availability of moisture and rate of decomposition
- after 21 days the piles are uncovered and the ready compost is sieved

According to Mr. Kamau, thermophilic temperatures between 50°C and 70°C are maintained for 2-3 consecutive days. In the background of the picture (Figure 31) the compost heaps covered with banana fibres are visible. The plant capacity is estimated at about 2 tonnes, though no record is available. All workers on the plant are volunteers and receive only little payment through the sale of compost. The sieved compost is sold to NAWACOM fertiliser manufacture for 6 Ksh (0.07 €) per kilo. Maintenance is done by the group though they lack manpower.

5.2.2 NAWACOM Fertiliser Manufacture

Also on April 16th the NAWACOM fertiliser manufacture was visited. Practical Action through its donor organisation 'Comic Relief' granted most of the investment. The establishment is run by NAWACOM in collaboration with Egerton University and Practical Action. Here, the compost is further manufactured to obtain a high quality organic fertiliser, sold as 'Mazingira Organic Fertiliser'. Compost is bought from the compost plant at the dump-site and from smaller composting plants in the peri-urban areas. Before the compost is bought, it is sampled for quality. Then it is processed to organic fertiliser. The NAWACOM chief executive officer Mr. Mwangi explained the process as follows:

- at first the received compost is sieved and stored (heaps are covered but N loss is still around 65%);
- phosphate is added as P is very low in the compost;
- a plant-water mixture, which has been fermented for 2 – 4 weeks[45], is added to the compost for N enrichment (see Figure 32 right side)

The obtained organic fertiliser is analysed by Egerton University for its nutrient content and then packed into bags of different sizes. Figure 32 shows one of these bags on the left side (5 kg unit). The N-P-K value is said to be 2.0-1.5-1.8 (percent of dry matter). The fertiliser is sold at 1000 Ksh (11.09 €) per 50 kg bag, whereas a 50 kg bag of

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[45] A species frequently found on roadsides in Kenya called *tithonia diversifolia* is used for this process. The green leaf biomass of this plant is high in nutrients (N, P and K).

chemical fertiliser would cost 1750 Ksh (19.40 €)[46]. To promote the fertiliser, in and around Nakuru several demonstration sites, showing the plant growth enhancement, were established. NAWACOM has links to the Ministry of Agriculture and to farmers associations to improve the marketing. Furthermore promotional prices of 1750 Ksh (19.40 €) for 150 kg organic fertiliser[47] try to attract more customers. At the time the case study was conducted the sales volume was estimated to be around 6 tonnes per month. However, this was during the growing season and compost sales usually drop significantly during non-growing seasons.

Farmers in the Nakuru area seem to prefer organic fertiliser to chemical fertiliser – even if the total N-P-K is lower. This is due to the fact that the chemical fertilisers are leached quickly during the wet growing seasons (when fertiliser is usually applied and also needed most by the plants). The organic fertiliser releases the nutrients slower and has thus a prolonged fertilising effect.

Figure 32: 5 kg fertiliser bag (left) barrels containing a *tithonia diversifolia* and water mixture (right)

46 However, it is not known what sort of chemical fertiliser this price relates to.

47 That means 3 bags organic fertiliser for the price of one bag of chemical fertiliser.

5.3 The Possibility of Co-Composting

5.3.1 Background Information

Thermophilic composting is very appropriate for sanitising and stabilising FS, faeces that have been pre-treated in a urine diversion toilet or slurry from anaerobic treatment. If operating conditions required for thermophilic composting are adequate (moisture content 50-60 °C, C:N ratio 30-35 and mixing of bulking material to allow for sustained air passage), the temperature normally rises to between 50 and 65 °C. Such high temperatures will effectively inactivate pathogens. Fresh FS is normally too wet and exhibits a too low C:N ratio for optimal composting. FS thus has to be dewatered prior to co-composting, or alternatively admixing of a relatively dry, carbon-rich bulking material is required. (WHO 2006)

Co-composting FS (or bio-digester slurry) and organic waste is advantageous because the two materials complement each other. FS is relatively high in N content and moisture and organic waste contains large quantities of organic carbon and has good bulking quality. In theory, compost made with FS should exhibit higher nutrients than compost, which is produced from organic refuse, which contains material with N contents lower than in human waste. However, nutrient (notably N) contents are not particularly high when compared with the ranges for composts produced from organic waste. The reason for that might be due to N (ammonia) losses during pre-composting storage and treatment (e.g. by dewatering on sludge drying beds) of the human waste. (Strauss et al. 2003)

Urine can be used as a starter for composting of organic waste. The use of urine has several benefits: it saves water, it provides missing nutrients to compost and it enhances the composting process (Bark et al. 2003). Organic waste on which urine is applied will decompose more quickly and composting temperature will be higher than without application of urine (Pinsem et al. 2002). The composting time can be shortened by around 20% (Ngilangil 2005). Although large quantities of N get lost through the evaporation of ammonia, the received compost has high nutrient values making it a good fertiliser (Pinsem et al. 2002).

Unfortunately only scanty information exists on organisational, institutional, and financial aspects of co-composting practices and schemes operated in developing countries (Strauss et al. 2003).

5.3.2 Some Thoughts on the Existing Composting-Plant

The composting plant situated at the dump-site is basically not consistent with any environmental standards. There is no leachate control and operators do not wear any protection clothes/ gloves. As the surrounding environment is an open dump-site which anyway releases large amounts of heavy metals into the local ground-water (Njuguna 2001), the lack of leachate control is not surprising. Furthermore, the composting workers who live on the dump-site pick their food out of the waste and often walk around barefooted. Thus, they are exposed to so many harmful pathogens and substances in their everyday live, that operating the composting plant would probably hardly make a difference. The setting is quite special and environmental standards might seem dispensable. Nonetheless, if the use of human excreta in the composting process is aimed for, measures for environmental and health control must be taken. Human excreta may contain high concentrations of pathogens which could infect workers and together with nitrogens could further pollute groundwater reserves.

It should be targeted to improve the living conditions of the people at the dump-site. A regular payment for their work would ensure that basic needs can be met. This would in turn guarantee that the employed staff can see the benefits of making a good job.

5.3.3 Suitability of the current composting activities for human excreta use

Possible scenarios for the use of human excreta in composting in Nakuru could be for example:

I. Co-composting of FS (and/or slurry from anaerobic digestion) and municipal organic waste at the composting plant

II. Co-composting of faecal matter from urine diversion toilets at the composting plant

III. Use of urine in the composting process at the composting plant

IV. Use of urine (as an alternative to *tithonia diversifolia*) to upgrade compost-quality at the fertiliser plant

I. Co-composting of faecal sludge (and/or slurry from anaerobic digestion) and municipal organic waste at the composting plant

Although treatment recommendations by the WHO (2006)[48] could be met with the current operation, co-composting of faecal-sludge on the existing composting plant is not possible. Larger investments for sludge-drying facilities (including treatment of the fluids) and leachate control (by a sloped and sealed surface with a surrounding drainage system (Strauss et al. 2003)) would be necessary.

Furthermore, O&M must be carried out and monitored on a professional basis, which would mean that the MEWAREMA workers need to be trained in management, bookkeeping etc. A volunteer based operation might not be suitable for a co-composting plant as steady operational care is necessary to ensure adequate pathogenic risk control. As volunteers do not get paid for their work on a regular basis, they normally always have other income generating activities which might conflict with the operational care for the composting plant. However, if the produced compost can be sold at rea-

[48] Temperatures above 50 °C should be obtained in all material for at least one week. Times may need to be modified based on local conditions.

sonable prices, a good financial management and marketing strategy might turn volunteers into paid workers.

II. Co-composting of faecal matter from urine diversion toilets at the composting plant

Dried faecal matter from dehydrating toilets has the advantage that it contains little water making transport cheaper. Co-composting of dried faecal matter and organic waste at the dump-site might prove less challenging than the latter. There would be no need for additional sludge drying facilities subsequently investment and O&M costs would be less. However, leachate control is still necessary as Guness et al. (2006) have shown that pathogens can be leached out of dried faeces and eventually reach ground-water. For O&M the same recommendations as for the faecal-sludge scenario are given.

III. Use of urine in the composting process at the composting plant

Urine could be used for watering the compost instead of water. The moisture in the urine would evaporate during thermophilic composting and leave some of the nutrients (mostly P and K) in the compost. If the urine is delivered to the plant by a vacuum tanker it could be stored in a PVC tank, normally used to store water, and application can happen with the help of a hose. If the urine is delivered to the plant in barrels or jerry cans, storage and application can be done without an intermediary storage tank. Investments costs only occur for the tanks/ barrels or jerry cans. However, transport cost can be significant, depending on the haulage distance and the required volumes. O&M would not differ greatly from the original set-up if the urine has been given enough time to sanitise before application. Otherwise health protection measures for the plant workers have to be considered as the urine possibly contains pathogens.

IV. Use of urine to upgrade compost-quality at the fertiliser plant

As described before, the compost delivered at the NAWACOM fertiliser plant is enriched with nutrients to make it a high quality fertiliser. Urine with its fertilising value offers itself as such an additive. Instead of fermenting local plants, human urine could be used to enrich the compost. A simple calculation however shows that huge amounts of urine would be needed to substitute for the current enrichment with nutrients from *tithonia diversifolia* and the added P:

50 kg of ready organic fertiliser contain 1kg N, 0.75 kg of P and 0.9 kg of K (based on N-P-K value of 2.0-1.5-1.8). From chapter 3.2.1 (Faeces and Urine) follows that one person excretes around 550 l of urine per year. Furthermore the yearly excretion of nutrients through urine is said to be about 3 kg of nitrogen, 0.3 kg of phosphorus and about 1 kg of potassium. Subsequently, one needs 183 l of urine to enrich 50 kg of compost with sufficient N (assuming there is no N in the compost and all N from urine can be transferred to the compost). Figures get worse concerning K and P. Based on the same assumptions; one would need 495 l to enrich 50 kg of compost with K and 1375 l for enrichment with P (see Equation 1 for the calculation).

$$x = y \bullet (\frac{a_n}{b_n})$$

x = required volume of urine to enrich 50kg of compost with the nutrient n [l]

y = average excreted volume of urine per person per year (550 l)

a_n = mass of nutrient n in 50 kg organic fertiliser [kg]

b_n = average mass of nutrient n excreted through urine per person per year [kg]

Equation 1: Required volume of urine to enrich 50 kg of compost

The calculation is simplified - some assumptions were made which may falsify the results - however, even if only half of the calculated volume of urine is needed, the process of enrichment would already be too difficult to manage. If the required amounts are mixed with the compost for enrichment, the water from urine will have to be evaporated without loosing to much N, or a method of continuous stream accumulation has to be applied. Both solutions would require expensive investments in technology. Thus, this scenario is not recommended as low-cost methods to concentrate urine have not been developed yet and the application of non-concentrated urine in such large quantities is impossible.

Conclusion

The current composting activities aim at producing rather small amounts of high quality fertiliser for which the demand is given. Before a large scale co-composting of faeces or FS can be opted for, demand for large quantities of compost has to be assessed. Without this demand - even if donor finance for the capital investment would be given - composting will not be sustainable as sales revenues are needed for paying the O&M costs. An alternative would be to produce less expensive, lower quality compost if the demand for such a product is higher. Investment costs for a co-composting plant are high for the FS scenario and moderate for pre-treated faeces.

Upgrade of the compost quality at the composting plant through urine seems to be promising as it would not require large investments, would save water and still could raise the revenues from compost sales for the MEWAREMA people. The compost could be sold at higher prices, because of its increased nutrient levels. Urine application in the fertiliser plant has proven to be impossible due to the low concentration of nutrients in urine.

5.4 Wastemanagement in the Peri-Urban Areas

Several visits to the peri-urban areas were conducted during the case study. When walking through the low-income settlements the first thing one recognises is the solid-waste polluting the peri-urban environment. Roads, lawns and stormwater drainages are polluted with household waste (mostly plastic bags and organic waste[49]) as can be seen in Figure 33.

Figure 33: Top: Household waste polluting urban environment; Bottom left: Storm drainage filled with solid waste; Bottom right: Stormwater and greywater flooding a road;

It is very apparent that neither the municipal waste services nor private service providers are active in the outskirts of town. Blocked storm drainages subsequently lead to flooding in the rainy season and the solid waste is often carried down to the Lake Nakuru National Park. Greywater is often disposed onto roads (Figure 33) and further

[49] Recyclable goods are picked out by salvagers who can earn some cash by selling plastics, glass, metal, bones etc. and by composting the biological fraction.

adds to the unhealthy living conditions. When talking to people, the waste problem also seems to be their major environmental concern. Sometimes CBOs do some cleaning, but these groups are only active for a very limited area and time. Pit latrines discharging directly to storm drainages could not be found.

Appendix D shows a map of Nakuru detailing the service coverage of solid waste collection services. It can be see that only central areas are served by the municipality. Private service providers collect waste in some other parts of the town. However, large parts and especially the peri-urban areas are left out and community initiatives are expected to step in. To facilitate more organised waste collection, 14 central collection points were established with support from World Wild Life Fund for Nature (WWF) several years ago. These are small roofed buildings that are accessed from staircases. The idea was that neighbourhood collection services would bring the solid waste to these refuse chambers and municipal services then could easily load the waste onto their collection vehicles. However, as can be seen in Figure 34 (top and bottom left) these collection points are in a deteriorating state. As the municipality would not pick up the collected waste, the collection points finally had to be abandoned. A written message on the walls of the roofed collection points says “No Dumping” which is quite paradoxical for a waste collection point. Additionally, there are many small collection chambers made of masonry and normally attached to houses or walls in some peri-urban areas (Figure 34, bottom right). These will only be emptied in that areas which are served by waste collection - which is obviously not the case for the collection chamber on the picture (Figure 34, bottom right).

Figure 34: Central waste collection points in the Lakeview area (top and bottom left); Small waste chamber adjoining to a property (bottom right)

5.4.1 Interview with a Municipal Officer

On April 24th 2007, a semi-structured interview was conducted with Mr. Kamau from the municipal department of Public Health. Mr. Kamau is the head of the waste management section and was willing to answer some questions during a one hour interview. Some basic questions were noted before, but the interview was structured quite flexible to adapt to emerging issues. The aim of the interview was to find out more about the arrangements in waste collection services. Stakeholder participation, financing and problems with O&M were among the issues that should be focussed on.

According to Mr. Kamau, the municipality can not cope with the speed of urban growth in Nakuru. Main constraint here is the shortage of resources. As a reaction the municipality decided to aim for a stronger involvement of the private sector and community groups in waste management. The whole city is subdivided in zones where either the municipality or the private service providers do the collection (see Appendix D). Private service providers have to bid for the contract and then get awarded by the municipality. Private sector involvement is possible where there is ‘money in waste’. That means that collection services will only operate where regular and sufficient payments for the service can be expected[50].

Waste fees are fixed by the municipality and are graduated according to the income patterns (compare ‘cross-subsidisation’ in chapter 4.7.2: Subsidies). Fees are:

- 100 Ksh (1.11 €)/ month for low-income areas
- 150 Ksh (1.67 €)/ month for middle-income areas
- 200 Ksh (2.22 €)/ month for high-income areas

For the remaining zones (large parts of the peri-urban areas), policies and guidelines were developed for community work. The municipality tries to stimulate volunteer work - this happens together with other stakeholders (NGOs, CBOs). One way of advertising for volunteer work is at open meetings where private comedian groups attract people. Here papers are distributed and some advertising takes place. However, mobilising of volunteer groups is very difficult, not at least because funding of these groups is a major problem (An innovative, community-based financing method will be shortly described in the next chapter). Later in April 2007 a new by-law will be released by the community. According to Mr. Kamau, this by-law will make it necessary for the citizens of Nakuru to subscribe with a service provider – this should ensure that people really pay for the delivered service. However, enforcement of this law will prove quite difficult.

In the interview Mr. Kamau told about a grant from the Italian government given to the municipality in 1988 or 1989. This grant was in form of a consignment for service equipment for urban waste management. The municipality received 2 vacuum trucks, 2 big trucks for waste collection, 2 smaller trucks (so called ‘Minimatic’ trucks) and a number of waste containers (3 different types). The smaller Minimatic trucks would collect the waste from containers and compress it. Then the compressed waste would be unloaded into bigger containers (called ‘Packtainers’) which are able to further compact the waste. Finally the larger trucks would lift the Packtainers and transfer the waste to the dump site. However, most of this equipment is not in use anymore – the municipality was not able to carry out sufficient maintenance and most vehicles and containers are rotting at the municipal depot, nowadays. According to Mr. Kamau, this is due to a lack of spare parts for the collection vehicles. As the equipment represented an interdependent waste-collection system, the breakdown of some collection vehicles led to the other equipment being useless. This is a sad example of a non-sustainable investment due to neglect of spare parts provision and probably an example of bad maintenance by the operators.

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[50] In the low-income settlements this is often not the case as people are very poor and many have the perception that this kind of service should be offered for free.

Some days after the interview, the municipal depot was visited to capture some of this equipment on a photo. Figure 35 shows one of the Minimatic trucks (top left), several Packtainers (top right) and three waste containers (bottom). It was obvious that all of this equipment is no longer in working condition.

Figure 35: Rotten waste management equipment at the municipal depot

When asking Mr. Kamau what he supposed to be the major constraints the municipality is facing (in regard to service provision), he highlighted the following points:

- Lack of financial resources (low revenue base and too little government funding)
- Non-payment by the citizens (due to lack of trust, disappointment and/or because people feel services should be offered for free)
- Bad management from sides of the council
- Mobilising and funding of volunteer groups is very difficult

<u>NAHECO</u>

The ‘Nakuru Affordable Housing and Environmental Committee’ (NAHECO), is an umbrella association of community-based groups made up of urban poor from seven low-income settlements in Nakuru. The groups came together with the aim of solving most pressing incomes, shelter and environmental needs within the municipality. NAHECO has changed its status to a Savings and Credit Cooperative Society (SACCO) under the cooperative act in 2001, mobilising members' savings and administering housing and micro-enterprise loans (Post, Mwangi 2006).

The community members through their groups are shareholders and can easily access credit to invest in small enterprises. The SACCO, through offering credits for small businesses, can be seen as a good micro-finance tool for facilitating small scale service providers to collect and recycle solid waste in the low-income areas.

6 Discussion and Conclusion

The web-based literature survey could identify a large set of documents available on topics related to O&M. Most of the literature could be downloaded for free, as it seems to be usual in the WSS sector (especially in relation to development work). Although literature on the special topics of O&M and management of decentralised sanitation systems in developing countries is very scarce, some knowledge exists. This knowledge can be found in project reports, case-studies or in books covering various aspects of sanitation. The few identified documents dealing with O&M exclusively were very helpful in identifying important aspects and sub-topics of O&M and subsequently assisted in identifying key-words for in-depth search on these aspects. Most of the literature used for this thesis is on aspects inherent to O&M and was found by using related keywords – for example ‘cost-recovery in sanitation’ or ‘community management’. This is also reflected in the thesis – all aspects of O&M are described separately. Some might argue that this ‘splitting’ makes it hard to find a red line; However, O&M is such a complex issue that all its aspects can only be considered sufficiently when they are seen as separate entities which all need to be integrated in the overall framework of project planning. The ‘key issues’ boxes at the end of every larger chapter try to highlight the most important aspects of the chapters and may serve as a guide through the document.

The research question on the necessary framework conditions for sustainable O&M could be answered, but not in detail. Although a general framework could be provided by describing important factors and processes impacting on O&M and vice versa, a guideline detailing a framework which would include all aspects necessary for sustainability can not be given. The influence of local conditions and political and economic changes make such a guideline impossible. Necessary conditions may vary in time and place, although the overall framework prevails. A general framework has to include environmental, legal, institutional, socio-cultural, financial and technical factors and processes. Impacts of O&M on the environment and vice versa should be seen in the context of sanitation concepts and their interrelations with the environment and human health. Emissions to different recipients (water, soil, and air), resource use by different sanitation systems during O&M and the quality of the treatment product for possible reuse are among the environmental criteria which need to be considered. The importance of proper legislation which is appropriate to resource-oriented sanitation and to a multi-stakeholder approach has been shown. Institutional arrangements in the context of decentralisation have to involve all ‘local players’ in sanitation as well as the community to be sustainable. A large set of stakeholders will lead to scattered responsibilities in O&M, thus communication on all levels and coordination of activities are crucial and need to be managed by an overall-coordinating agency. Users need to be part of planning, implementation and O&M; however it is unclear if the concept of community as an entity (or smaller entities) can be maintained in rapidly growing urban conglomerations. (Larger) CBOs, seem to be an appropriate form of community involvement in

O&M and management on municipal level. Demand for sanitation improvement, the perception of excreta reuse, gender and tenancy status of users impact on O&M and should be assessed (and results incorporated into the planning process). Information, education and support activities are a prerequisite for sustainability and should take place before, during and after the implementation stage. Selection of technology must integrate users demand, informed choice (on the basis of O&M requirements, costs etc.), know-how by sanitation experts and sustainability criteria. Availability of spare parts is essential.

Management and partnership options for O&M and for sanitation systems in general have been identified, and discussed. Although knowledge on local management models in sanitation is limited, a variety of options exists and experiences in related sectors like water supply and waste management are helpful. The chosen management model, however, always has to reflect the local conditions and the selected sanitation systems. Management options consist in a blend of ownership and responsibilities between the public sector, the private sector and user associations. Management by the local authority is only possible where the capacities are given and the chosen arrangements can supply all areas and communities with adequate services. Community involvement in management is desirable; however, several constraints do exist for community management, especially in urban areas. Private sector involvement is already prevalent in the sanitation sector in most towns. Entrepreneurs' role has to be strengthened by an appropriate policy framework and informal providers have to be recognised, regulated and supported by the government. PPPs offer a wide spectrum of possible formal contractual arrangements, but servicing poor-areas can pose a problem due to the (perceived) low cost-recovery possibilities.

Financing strategies and possible financial resources for cost recovery have also been identified. This issue has to be seen as very critical in developing countries, where financial resources are always low. The problem has two sides – on the one hand large deficits in financial management, corruption and bad governance hamper financial sustainability, and on the other hand the economic overall situation of these countries does often not allow for significant development. Through the use of intelligent cost-recovery mechanisms, adapted to the local (income) situation, and by various alternative financial mechanisms, the limited resources available can be used more effectively and equitable. Cost-recovery from users is seen as a critical factor for success and various methods for user and community financing can be applied. Private-sector involvement must be stimulated and supported where it is possible. Guidelines for private-sector involvement and PPPs exist and should always be used to ensure sustainability and equity. Reasonable sums are invested by international donors in development projects. Ideally, in the context of sustainability, there should be a shift from spending these resources on new infrastructure and hardware to the support of O&M of existing facilities.

The case study, although limited in time, revealed interesting characteristics of Nakuru's situation in regard to O&M. Most of the information gathered was by asking local people – sometimes more formally, with appointed interviews, but often rather informal.

Semi-structured interviews (or interviews in general) do not allow for a strict verification of all information. Some cross-checking was done by asking different stakeholders the same questions, but the given information could not be assessed on an empirical basis. Some tension between the MCN and the citizens was detected – most of the citizens are not served by the municipality and lost their trust. Furthermore, bad governance and corruption are known to exist in Kenya and people are suspicious about governmental authorities[51]. Thus, it is not surprising that this atmosphere also influences the answers one gets when asking questions concerning this relationship. For example, during the interview with the municipal officer, it was stated that the municipality does encourage CBO involvement in garbage collection and gives support by teaching technical know how. However, the information that this CBO groups actually have to pay a so called 'inspection fee' to the municipality[52] was never an issue. This example highlights that the information one gets is always 'pre-filtered' – this has to be regarded.

Nakuru is very unique concerning CBO activities, stakeholder communication and partnerships. Involvement of the poor in participatory planning, however, is not happening directly. The only way for a poor person to have influence on planning is by being member in one of the bigger CBOs. There is a vast variety of local CBOs with NAHECO and NAWACOM as umbrella CBOs being the biggest ones. NGOs are other important players in Nakuru, and Practical Action is especially successful in attracting donor grants and in the implementation of projects. The creation of an environmental consortium can be seen as an important step in involving the MCN into these activities, although no details on the structure of this consortium are known. Involving the municipality as a whole institution into a participatory process together with other stakeholders is critical for future success. The MCN has to see its role as a facilitator for community and private-sector involvement as it can not fulfil its role as a service provider on its own (compare with chapter 4.2.2: Decentralisation). MCN guidelines development for community work is a good step towards institutionalisation of an interface between the MCN and CBOs. However, success in service improvement is highly needed to create a feeling of hope and trust into community work (from the MCN's side) and into the MCN (from community's side).

Composting and fertiliser marketing experiences in Nakuru are something to build on, although the activities offer limited possibilities for co-composting of human excreta at their current scale. Urine addition to the composting process is recommended if transport and storage could be ensured. Installation of a co-composting plant should only be opted for, if demand for larger quantities of compost has been detected and stimulated. The current set-up seems to generate sufficient revenues to keep the programme running, although the marginal payment to the MEWAREMA groups (and other composters) has to be seen critical. Maintenance at the composting plant has been reported

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[51] However, it was interesting to find out that this atmosphere of mistrust is mainly between the MCN as an institution and citizens but usually not between citizens and people working for the municipality.

[52] Found in: (Post, Mwangi 2006)

difficult - MEWAREMA people lack expertise and money. Management through the cooperative society NAWACOM seems to work well. NAWACOM is very well organised and is able to attract support and funding from NGOs. This is probably due to its size – NAWACOM operates in a wide area and seems to have bigger bargaining power compared to other CBOs.

In waste management, two outstanding examples for bad O&M leading to hardware break-down or disuse were identified:

- The waste collection vehicles and containers provided by a foreign government
- The waste collection chambers installed by WWF

Both investments were probably made without considering O&M to the needed extent. Spare parts and sufficient capacity for O&M were lacking in the first example (vehicles, containers). It is undeniable that either O&M has not been considered by the donors or that the donor country expected the MCN to import spare parts from this country. The second example also shows that an installation of facilities alone does not necessarily lead to an improvement of the situation. Provided waste chambers are not in use anymore, because there is no capacity to operate them. Both examples highlight the importance for donors to also plan (and finance) for O&M, even if such activities seem less prestigious.

7 Recommendations and Open Questions

At first some recommendations are given based on the results of the literature survey and case study. The recommendations are given as general recommendations and recommendations for Nakuru. Finally some open questions/ research gaps are presented to stimulate research on these issues.

<u>General recommendations are:</u>

1. **Create O&M awareness among stakeholders**
   All stakeholders must be made aware of the importance to integrate O&M into planning. Furthermore, factors and processes influencing O&M and management and financing possibilities should be detailed to all partners.
2. **Improve coordination between stakeholders**
   In a multi-stakeholder approach, it is not sufficient that each partner 'does its best' in O&M. There must be coordination in action and communication on all levels. Regular meetings are a good way to exchange information and there must be a responsible organisation for coordination.
3. **Transfer knowledge**
   There will always be key persons and organisations who do incorporate a lot of knowledge on O&M. It is very important to transfer and share this knowledge with other stakeholders. This is especially important if key persons in O&M are leaving – without a sufficient transfer of knowledge to the remainders, major drawbacks in O&M are likely.
4. **Optimise O&M of existing systems**
   O&M of the existing facilities and infrastructure can always be optimised. This will usually result in more instant and sustainable benefits than investment in new facilities.
5. **Integrate peri-urban agriculture into sanitation planning**
   As peri-urban agriculture is widespread in many areas, it should be seen as a chance to close nutrient and water loops locally. This would have many benefits, for example: cost savings in O&M, yield increases for peri-urban farmers and promotion of resource-oriented sanitation

<u>Recommendations for Nakuru are:</u>

6. **Link urine-diversion with composting**
   Collected urine should be used in the composting process to enhance compost quality – either at the composting plant at the dump-site or at one of the peri-urban 'satellite composter'. Urine collected at the public toilet in town is available for trials.
7. **Be careful when encouraging community involvement**
   Community involvement in service delivery must only be encouraged from MCN

side if there is more to offer than just the 'willingness to involve the community'. There must be commitment from officials and financial guarantees (from MCN or donor agencies). Otherwise frustration increases and leads to even less trust into partnerships.

8. **Cooperative association of public administration as a management model**
A cooperative association of public administration could be an appropriate management model for a future town-wide resource oriented sanitation approach. Several stakeholders could be integrated into management in an organisation under private law (see chapter 4.5.6: Cooperative Association of Public Administration). This management model would also reflect the already existing environmental consortium. However, this recommendation is based on limited information and of course the local conditions have to be assessed in detail before opting for this model.

<u>Open questions are:</u>

- Linking peri-urban agriculture with excreta reuse is hardly addressed in research. There is little information on possibilities and implications of doing so.
- There is little knowledge on models for decentralised management of sanitation systems in peri-urban areas.
- There is a lack of information on O&M requirements and O&M cost data for different (resource-oriented) sanitation systems regarding the collection, the transport, treatment and end use of the excreta and reclaimed water.
- Urine collection, transport and storage are a major challenge for urine diversion sanitation approaches on a large scale in (peri-) urban areas of developing countries. Alternative collection, transportation and especially storage methods need to be explored.

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9 Appendices

9.1 Appendix A: ROSA - Resource-Oriented Sanitation Concepts for Peri-Urban Areas in Africa

9.1.1 Project Description

The ROSA project proposes resource-oriented sanitation concepts as a route to sustainable sanitation and to meet the UN MDGs. These concepts shall be applied in four pilot cities in East-Africa, namely Arbaminch (Ethiopia), Nakuru (Kenya), Arusha (Tanzania) and Kitgum (Uganda). These cities have a population of several 10'000 inhabitants and represent typical cities in East Africa. All pilot cities have common problems, e.g. that they are situated in dry regions resulting in a lack of water. Another problem for all cities is the relatively high growth rate of the population. Sanitation facilities and the people in the pilot areas are poor, there is lacking sanitation and waste management.

ROSA is a Specific Target Research Project in the EU 6th Framework Programme's Priority 6 ‘Sustainable development, global change and ecosystems’. It started in October 2006 and will be financed for three years. The coordination of the project is assigned to Dr. Günther Langergraber, from the University of Natural Resources and Applied Life Sciences Vienna, Austria.

The project is composed of five European partners active in the field of resource-oriented sanitation and eight East-African partners, one university in each of the four countries and the responsible authority of every town.

European partners:

- University of Natural Resources and Applied Life Sciences Vienna, Inst. of Sanitary Engineering, Austria
- Hamburg University of Technology, Institute of Municipal and Industrial Wastewater Management, Germany
- Ecosan Club, Austria
- WASTE Advisors on Urban Environment and Development, The Netherlands
- London School of Hygiene and Tropical Medicine, Disease Control & Vector Biology Unit, Department of Infectious and Tropical Diseases, UK

African partners:

- University of Dar es Salaam, Department of Water Resources Engineering, Tanzania
- Makerere University, Department of Civil Engineering, Uganda

- Egerton University, Department of Water and Environmental Engineering, Kenya
- Arbaminch University, Research & Publication Coordination Department, Ethiopia
- Kitgum Town Council, Uganda
- Arusha City Council, Tanzania
- Municipal Council of Nakuru Department of Environment, Kenya
- Arba Minch Water Supply and Sewerage Enterprise, Ethiopia

9.1.2 Project Objectives

Adaptable, affordable and replicable solutions for sanitation of peri-urban areas in the pilot cities that are based on source separation shall be developed. For sustainability of the implemented solutions integrated stakeholder based management concepts will be developed and tested including end-users, service providers and authorities. For all pilot cities strategic sanitation and waste plans (SSWPs) will be developed for the whole city area. These SSWPs will come up with the best solution for the city combining several techniques according to the local requirements. Within the project the focus of implementation will be in the peri-urban areas away from the city centres. Mainly because the peri-urban areas have the most pressing need for low-cost sanitation based on livelihood improvement and sustainable concepts. Experience with innovative source-separating sanitation systems are mainly rural up to now and further research will be necessary to adapt management and technology of these systems to the peri-urban environment.

The specific research objectives addressed in the ROSA project are focused on applied research and include:

- an implementation study of the updated WHO-guidelines for use of waste and excreta in agriculture and aquaculture in peri-urban areas and the integration of resource-oriented solutions in regulatory frameworks
- the development of operation and management strategies for peri-urban areas
- the development of decentralised solutions for greywater treatment in arid and semi-arid areas including the optimisation of constructed wetland design taking into account the local conditions
- the integration of resource-oriented sanitation into local settlement structures
- the development of local structures for financing of sanitation.

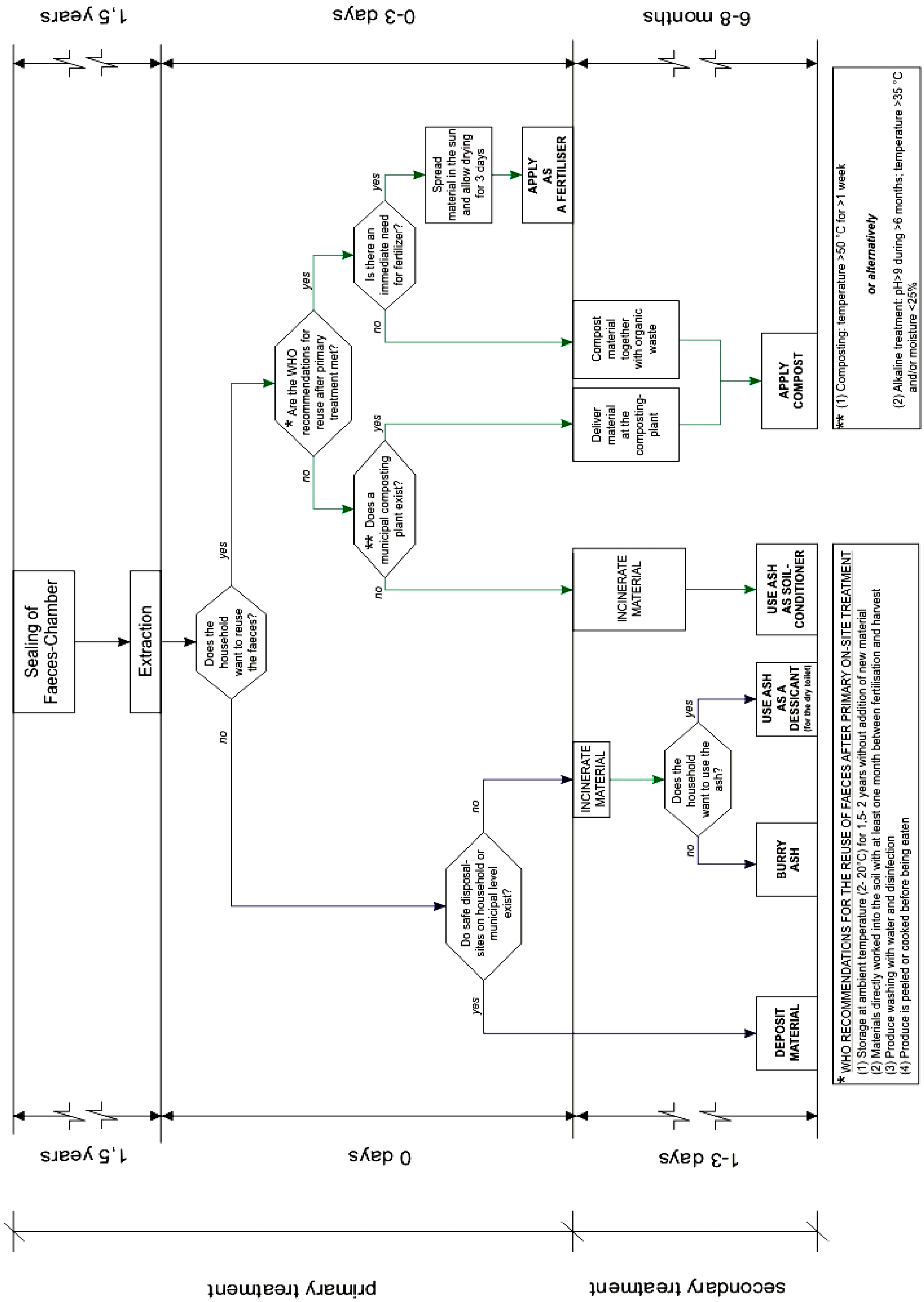
The implementation phase within the ROSA project will be focused on the peri-urban areas of the pilot cities. However, for the remaining parts of the cities the consortium will develop possibilities for financing the implementation of the whole SSWP.

Among other objectives, the ROSA projects targets the development of community based operation and management strategies for resource-oriented sanitation concepts.

The following description of this research topic is taken from the project proposal (Langergraber 2005):

"Community based operation and management strategies for resource-oriented sanitation concepts shall be developed and investigated. Well prepared structures for O&M of the sanitation system are mandatory for its acceptance. This includes the user behaviour as well as the support by the O&M company which has to be built up and trained in the frame of the project. This includes an intensive training of the staff in emptying the dry toilets, collecting the liquid and solid fractions of the human disposal and transporting them to the utilisation areas. An important aspect in this context is the integration of excreta-based products into local agricultural and resource-management activities, e.g. marketing of fertiliser and soil conditioner, reuse of water."

9.2 Appendix B: Flowchart for the Reuse of Faeces[53]



53 Adapted and translated from Sanabria (2007)

9.3 Appendix C: Operation and Maintenance of On-Site Sanitation Facilities

9.3.1 Operation and Maintenance of a Pit Latrine [54]

Operation of pit latrines consists of regularly cleaning the slab with water and disinfectant. Furthermore, the door must always be closed so that the superstructure remains dark inside. The drop hole should never be covered as this would impede the airflow. Appropriate anal cleaning materials should be available for the latrine users. Non-biodegradable materials should not be thrown into the pit, as this reduces the effective volume of the pit and hinders mechanical emptying. Every month, the floor slab should be checked for cracks, and the vent pipe and fly screen should be inspected for corrosion or damage, and repaired if necessary. The superstructure may also need to be repaired (especially light leaks). When the contents of the pit are about half a metre below the slab, the pit could be emptied mechanically. Alternatively a new pit could be dug and the old one covered with soil. Where latrines are used by a single household, O&M tasks are implemented by the household, or by hired labour. If several households use the latrine, arrangements have to be made to rotate the cleaning tasks, to avoid social conflicts. If pits are not emptied mechanically, they can be emptied manually, but only after their contents have been left to decompose for about two years. Otherwise, new pits must be dug when a pit is full. If double-pit latrines are used, the users need to understand the concept of the system fully to operate it properly. User education has to cover topics such as the reasons for using only one pit until the time for switch-over; the use of excreta as manure; and the need to leave the full pit for about two years before emptying. The users must also know how to switch pits and how to empty them, even if they do not do these tasks themselves. If the tasks are carried out by the private (informal) sector, the workers have to be educated accordingly.

Table 21: O&M - Actors and their roles

Actors	Roles	Skills required
User	Keep the latrine clean, inspect and perform small repairs, empty the full pit and switch to the new one, dig a new pit and replace the latrine.	Simple
Local unskilled labour (sweepers/ scavengers)	Dig pits, transfer structures, empty full pits in double-pit systems, perform small repairs, solve small problems.	Technical skill
Local mason.	Build, repair and transfer latrines.	Technical skill
Health department/ NGOs	Monitor latrines and the hygienic behaviour of users, educate users in good hygiene practices.	Highly qualified

Source: (Brikké, Bredero 2003)

[54] This chapter is adapted from: Brikké, Bredero 2003

Table 22: O&M technical requirements

Activity and frequency	Materials and spare parts	Tools and equipment
Daily		
clean the drop hole, seat and superstructure	Water, soap.	Brush, bucket.
Monthly		
inspect the floor slab, vent pipe and fly screen		
Every 1–6 months		
clean the fly screen and the inside of the vent	Water.	A twig or long flexible brush.
Occasionally		
repair the slab, seat, vent pipe, fly screen or superstructure	Cement, sand, water, nails, local building materials.	Bucket or bowl, trowel, saw, hammer, knife.
Depending on size and number of users		
dig a new pit and transfer latrine	Sand, possibly cement, bricks, nails slab and superstructure (if and other local building materials. applicable);	Shovels, picks, buckets, hammer, saw, etc.
switch to the new pit when the old pit is full;		Shovels, buckets, wheelbarrow, etc.
empty the old pit (if applicable).	By hand: water.	By hand: shovel, bucket.
	By mechanical means: water and spare parts for the machinery.	By mechanical means: equipment for emptying the pit.

Source: (Brikké, Bredero 2003)

<u>Potential problems</u>:

- the quality of the floor slab is poor because inappropriate materials were used in its construction, or because the concrete was not properly cured;
- inferior quality fly screens are easily damaged by the effects of solar radiation and foul gases;
- badly-sited latrines can get flooded or undermined;
- children may be afraid to use the latrine because of the dark, or out of fear of falling into the pit;
- if the superstructure allows too much light to come in, flies will be attracted to the light coming through the squat hole and may fly out into the superstructure, which can jeopardise the whole VIP concept;
- in latrines that rely on solar radiation for the air flow in the vent pipe, rather than on wind, odour problems may occur during the night and early morning hours;
- leakage between pits occurs because the dividing wall is not impermeable or the soil is too permeable;

- in hard soils it may be impossible to dig a proper pit;
- pits should preferably not reach the groundwater level and must be 15–30 m from ground and surface water sources;
- VIP latrines do not prevent mosquitoes from breeding in the pits;
- VIP latrines cost more to construct than simple pit latrines and the community may not be able to bear the higher costs;

9.3.2 Operation and Maintenance of a Septic Tank System

Regular cleaning of the toilet is necessary, but care has to be taken as large amounts of detergents or chemicals may disturb the biochemical processes in the tank. In aqua privies the amount of liquid in the tank should be kept high enough to keep the bottom of the drop pipe at least 75 mm below the liquid level. A bucket of water should be poured down the drop pipe daily to maintain the water seal, and to clear scum from the bottom of the drop pipe, in which flies may breed. Adding some sludge to a new tank will ensure the presence of beneficiary microorganisms and enhance the anaerobic digestion of the excreta. Routine inspection is necessary to check whether desludging is needed and to ensure that there are no blockages at the inlet or outlet. The tank should be emptied when solids occupy between one-half and two-thirds of the total depth between the water level and the bottom of the tank. Organisational aspects involve providing reliable services for emptying the tanks, ensuring that skilled contractors are available for construction and repairs, and controlling sludge disposal. Hardly any activities are required to operate the soakaway, except when the soakaway or septic tank overflows. Then the tank outflow should be cleaned and the delivery pipe unblocked, if necessary (Brikké, Bredero 2003).

Table 23: O&M - Actors and their roles

Actors	Roles	Skills required
User	Flush the toilet, keep it clean, inspect vents, control contents of the tank, contact municipality or other organisation for emptying when necessary, and record dates tank was emptied. Check the outflow tank and performance of the soakaway.	Basic skill
Sanitation service	Empty the tank, control tank and vents, repair if needed.	Technical skill
Agency	Monitor the performance of the tank and the teams that empty it, train the teams.	Highly qualified

Adapted from: (Brikké, Bredero 2003)

Table 24: O&M technical requirements

Activity and frequency	Materials and spare parts	Tools and equipment
Daily		
clean the squatting pan or seat and shelter	Water	Brush, water container
Monthly		
Check the outflow of the tank boxes and clean them	Water	Brush, tools to open the access
inspect the floor, squatting pan or seat, and U-trap		
Regularly		
ensure that the entry pipe is still submerged (for aqua privies)	Water	Stick
Occasionally		
unblock the U-trap;	Water	Flexible brush or other flexible material
repair the pipe connection to the soakaway	Water, materials for dismantling pipes	Brush, shovel and tools to open the access, and to dismantle connector pipes
repair the squatting pan or seat, U-trap or shelter	Cement, sand, water, nails, local building materials	Bucket or bowl, trowel, saw, hammer, knife
Annually		
control the vents	Rope or wire, screen materials, pipe parts	Scissors or wire-cutting tool, pliers, saw
Every one to five years		
empty the tank	Water, fuel, lubricants, etc.	Vacuum tanker (large or mini), or MAPET equipment

Adapted from: (Brikké, Bredero 2003)

Potential problems (Brikké, Bredero 2003):

- many problems arise if inadequate consideration is given to liquid effluent disposal
- large excreta flows entering the tank may disturb solids that have already settled, and temporarily increase the concentration of suspended solids in the effluent
- if the water seal is not maintained in an aqua privy, the tanks will leak and cause insect and odour problems
- this system is not suitable for areas where water is scarce, where there are insufficient financial resources to construct the system, or where safe tank emptying cannot be carried out or afforded
- if there is not enough space for soakaways or drainage fields, small-bore sewers should be installed
- aqua privies only function properly when they are well designed, constructed and operated
- the soakaway overflows – this is a particular problem if both toilet wastes and greywater are collected in the septic tank and the tank was designed for toilet wastes only

- the soakaway system is not suitable if there is not enough space or water, where the soil is not permeable enough or is too hard to dig out (bedrock), or where the groundwater is close to the surface

9.3.3 Operation and Maintenance of a Double Vault Composting Toilet

Like with every toilet, regular cleaning is necessary. Water used for cleaning should not be allowed to go into the latrine as it will make the contents too wet. Before the system can be used some absorbent organic material is put into the empty vault (layer of ashes, dry soil or lime) to ensure that liquids are absorbed and to prevent the faeces from sticking to the floor. After each use, paper, wood or bark chips, sawdust, ash or similar are added. Occasionally, compost or fertile topsoil, if available, should be added to provide the contents with important soil bacteria (Morgan, SEI 2004). The use of ash should not be extensive as this might raise the pH and inhibit the composting process. Organic household waste can be added. When the vault is about three-quarters full, the contents are levelled with a stick, the vault is filled to the top with earth, and the squat hole is sealed. The second vault is then emptied with a spade, after which it is ready for use. Emptying composting toilets constitutes a critical handling point. Proper protection measures should be taken if the material is not fully sanitised, and the material should be further treated or stored out of reach from people until proper maturation times have been reached. In addition to protective clothing (e.g. gloves and boots), normal hygiene and washing after the emptying operation are important (WHO 2006). If sanitised properly, the contents of the second vault can be safely used as fertiliser and soil conditioner. Potential users of a vault latrine technology should be consulted extensively, to find out if the system is culturally acceptable, and if they are motivated and capable of operating and maintaining the system properly. The project agency will need to provide sustained support to ensure that users understand the system and operate it properly (Brikké, Bredero 2003).

Table 25: O&M - Actors and their roles

Actors	Roles	Skills required
User/household	Use latrine, help keep latrine clean, inspect and perform small repairs, help to empty the pit and switch over to the new pit	Simple[55]
Local mason	Build and repair latrines	Technical skill
Local vault emptier	Empty the vault and switch over to the new vault, check the system and perform small repairs	Technical skill
External support organisation	Investigate whether the technology is appropriate, monitor users' O&M and hygienic behaviour and provide feedback, train users and local artisans	Highly qualified

Adapted from: (Brikké, Bredero 2003)

[55] Often requires gender-specific awareness-raising, and training activities to change behaviour and build capacity

Table 26: O&M technical requirements

Activity and frequency	Materials and spare parts	Tools and equipment
Daily		
clean the toilet and superstructure	Water, lime, ashes	Brush, water container
After each defecation or whenever available		
add bulking material	paper, wood or bark chips, sawdust, ash or similar	Pot to contain the material, small shovel
add organic household waste and fertile soil or compost	organic household waste, fertile soil, compost	Pot to contain the material, small shovel
Monthly		
inspect the floor, superstructure and vaults		
When necessary		
level the mound formed by falling excreta from time to time		Stick or other tool
repair the floor, superstructure or vaults	Cement, sand, water, nails, local building materials	Bucket or bowl, trowel, saw, hammer, knife
use humus	Humus	Shovel, bucket, wheelbarrow
Depending on size and number of users		
close the full vault after levelling and adding soil	Water, absorbent organic material	Shovel and bucket
empty the other vault, open its squat hole and add 10 cm of absorbent organic material before using		
Collection of composted faeces, or store the humus and/or use it directly		

Adapted from: (Brikké, Bredero 2003)

Potential problems:

- users do not understand how to operate the system properly and leave the latrine contents too wet, which makes the vault malodorous and difficult to empty
- users are too eager to use the latrine contents as fertiliser and do not allow sufficient time for the compost to become pathogen-free

9.3.4 Operation and Maintenance of a Double-Vault Dehydration Toilet with Urine-Diversion

The toilet can be cleaned with or without water, but it is very important that no, or only very little water enters into the faeces chambers. A bit of warm water and vinegar can be added periodically to the urine separator and to the urinal for avoiding smell and precipitation-blockages. For toilets with a u-bend stench trap, preventive cleaning of the u-bend and the pipe immediately behind it by use of caustic soda, acetic acid and/or a drain auger 1-4 times per year is recommended (Jönsson, Vinnerås 2007). For faeces collection only one chamber is in use, the other chamber is sealed. After each use, dry absorbents (sawdust, peat moss, dry soil, ashes, etc.) are sprinkled over the faeces to absorb moisture, increase pH, and minimise bad odours and insects. The exact amount of additives depends primarily on users experience with their own system, but generally one or two cups are a good rule of thumb (Werner et al. 2006). Before using a chamber, a 5 cm fine layer of prepared soil (two parts of fine dry soil mixed with circa one part of ash or lime) or compost must be placed on the floor (Deegener et al. 2006), in order to absorb moisture from the faeces and to prevent them from sticking to the floor. For single-vault models with moveable containers, the same procedure is recommended for the bottom of the boxes. Furthermore, it is important to level the mound formed by falling excreta regularly. Depending on the toilet's frequency of use, the faeces must be levelled weekly with a stick or other tool, and some more additives should be added. Depending on the vault's volume, the first vault can be used 6-18 months, whereas 1 year minimum is recommended by the WHO (2006) for tropical conditions and at least 6 months if alkalisation through addition of ash or similar substances can be facilitated (see Table 4 on page 25). On the sitting and squatting toilets, men must urinate whilst sitting-down. They should take care not to wet the faeces chambers. For public toilets or cultures where men don't like to sit, a urinal is therefore preferable. The urine is collected in a reservoir and should preferably be used as a fertiliser in agriculture or garden (Deegener et al. 2006). Paper used for anal cleaning can be dropped in the hole for excreta or collected separately in box or jar and burnt. If bad smells or flies are perceived, a check must be done to assure that there are no leaks in the urine hose. The toilet caretaker should check regularly if the chamber inside is not too wet. Humidity can also enter through a bad sealed slice or through the walls, if these are not tight, or too much water enters during cleaning the toilets. If humidity is too high, it is recommended to add absorbance material (Deegener et al. 2006). When one vault is full the vault is sealed and all openings are tightly closed, e.g. with lime mortar or clay (Werner et al. 2006). Seat risers in Central America are commonly sealed by putting a plastic bag tightly over the unused one (Sawyer et al. 2003). The second vault now comes into use instead. When the second vault is nearly full, the first vault has to be emptied. The procedure for moveable container system is to move the full container to the back (or side – depending on the design) and to put an empty container under the drop-hole. After at least 6 months of storage without addition of fresh faeces, the dehydrated faeces, now odourless, can be reused as a soil conditioner. For a collection system on municipal or communal scale transport to pre-treatment/storage areas is necessary. Potential users of a vault latrine technology should be consulted extensively, to find out if the system is culturally acceptable, and if they are motivated and capable of operating and maintaining the system properly. The project agency will need to provide sustained support to ensure that users understand the system and operate it properly.

Potential problems

- users are too eager to use the latrine contents as fertiliser and do not allow sufficient time for the faeces to become pathogen-free
- users do not understand how to operate the system properly and leave the latrine contents too wet (misuse by men which are standing whilst urinating, anal cleaning water is directed to the faeces chamber etc.)
- blocked or leaking urine pipes (Kvarnström et al. 2006)
- overflowing urine tanks because owners forgot to empty them (Chaggu 2004)
- possibilities of overuse/ misuse during gatherings, like funerals, weddings etc., drawing many people who do not know the system (Chaggu 2004)
- odour problems in systems without a stench trap (Jönsson, Vinnerås 2007)

Table 27: O&M - Actors and their roles

Actors	Roles	Skills required
User/household	Use latrine, help keep latrine clean, inspect and perform small repairs, help to empty the pit and switch over to the new pit	Simple[56]
Local mason	Build and repair latrines	Technical skill
Local vault & urine-tank emptier[57]	Empty the vault and switch over to the new pit, empty the urine tank, check the system and perform small repairs	Technical skill
External support organisation	Investigate whether the technology is appropriate, monitor users' O&M and hygienic behaviour and provide feedback, train users and local artisans	Highly qualified

Adapted from: (Brikké, Bredero 2003)

[56] Often requires gender-specific awareness-raising, and training activities to change behaviour and build capacity

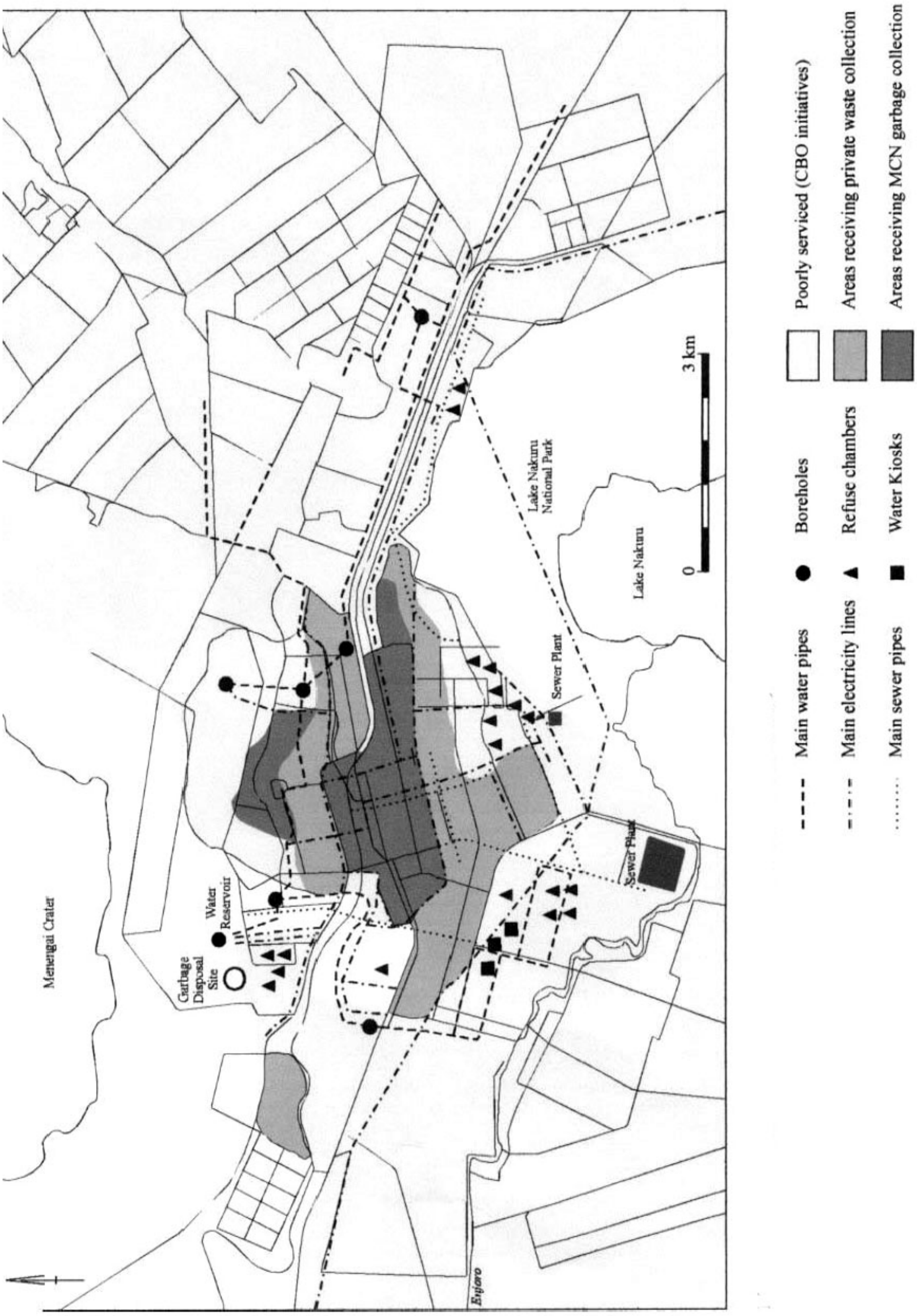
[57] If on-site reuse is practised this can be done by the users themselves.

Table 28: O&M technical requirements

Activity and frequency	Materials and spare parts	Tools and equipment
Daily		
clean the toilet and superstructure	Water, lime, ashes	Brush, water container
After each defecation or whenever available		
add desiccant	Sawdust, ash, dry soil	Pot to contain the material, small shovel
Monthly		
inspect the floor, superstructure and vaults		
When necessary		
level the mound formed by falling excreta from time to time and add some desiccant	Sawdust, ash, dry soil	Stick or other tool, pot to contain the desiccants, small shovel
repair the floor, superstructure or vaults	Cement, sand, water, nails, local building materials	Bucket or bowl, trowel, saw, hammer, knife
Clean urine pipes with hot water or vinegar	Hot water, vinegar	Pot
use humus/ urine as fertiliser	Humus, urine	Shovel, bucket, wheelbarrow. Jerry can/ watering can
Depending on size and number of users		
empty the urine container close the full vault after levelling and adding soil empty the other vault, open its squat hole and add 10 cm of absorbent organic material before using store the humus, or use it directly	Water, absorbent organic material	Shovel and bucket

Adapted from: (Brikké, Bredero 2003)

9.4 Appendix D: Structure of Services in Nakuru (Water, Electricity, Sewer and Solid-Waste Collection)



Source: (Post, Mwangi 2006)

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